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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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Junior Draughtsman Wanted.

One with knowledge of structural work, if possible. No one already on Government work or resident more than 10 miles away will be employed.—Address, giving full particulars and salary required, K 917, Offices of ENGINEERING.

Good Mechanical Draughts-

MEN WANTED by large controlled firm in Manchester district. Must be quick and accurate at detail work. No person already on Government work will be engaged. Apply, with full particulars, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 4731. K 944

Assistant (Male or Female)

REQUIRED in Estimating Office of Engineering Works, S.E. London; must be able to read drawings. Drawing Office experience an advantage. No applicants residing outside radius of ten miles or already employed on Government work can be engaged.—Address, stating age, experience and salary required, K 943, Offices of ENGINEERING.

Draughtsmen.—Good

mechanical MEN WANTED by electrical engineering firm in Lancashire for control gear, contactor and liquid type. Experience in this particular class of work not essential. Permanency to suitable men. No one already engaged on Government work will be engaged.—State age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5008. K 945

SUNDERLAND CORPORATION ELECTRICITY SUPPLY.

Wanted Immediately,

DRAUGHTSMAN with up-to-date experience of the lay-out of modern Electricity Works plant and the making and recording of Main Maps. Salary, including all bonuses to date, at the rate of £325 per annum.
Apply in own handwriting, stating age and details of experience, and how soon after appointment duties could be taken up, to
ALFRED S. BLACKMAN,
Engineer and General Manager.
Electricity Offices,
Dunning Street, K 948
Sunderland.

Wanted, a Capable Draughts-

MAN, who is accustomed to designing small high-speed steam turbines. He must be thoroughly conversant with the design and construction of all the latest types. No one already on Government work need apply and only those not eligible for Military service.—Apply, stating age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5020. K 963

Reinforced Concrete.—Ex-

perienced DRAUGHTSMAN WANTED for Concrete Shipbuilding. No one already on Government work or resident more than 10 miles away will be employed.—Address, stating experience and salary required, K 916, Offices of ENGINEERING.

First-class Draughtsmen

with good general experience WANTED by large Controlled Firm in South Yorkshire.—Address, giving full particulars of experience, and salary required (inclusive of War Bonus), J 348, Offices of ENGINEERING. J 348

Jig and Tool Draughtsman

REQUIRED, for Munition Works in North of London. No person already on Government work will be engaged.—Apply, stating particulars of experience and wage required, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5014. K 964

Lady Tracers Wanted at once

for important work, must be quick, accurate, and good at lettering; state salary, etc.—Address, K 949, Offices of ENGINEERING.

TEMPLETS, JIGS AND FIXTURES.—No. II.

By JOSEPH HORNER.

IN this and a succeeding article some examples of very massive jigs and templets will be illustrated. These afford a strong contrast with the designs which are used for the smaller manufactured articles. They represent the larger elements in marine engine construction, that of compound reciprocating engines in the present article, and that of steam turbine rotors and casings in the one to follow.

These differ primarily in the characteristic of greater massiveness from the jigs which are commonly handled, yet the same regard is had to precise fitting within fine limits. Strict standardisation is embodied, and related parts are carefully gauged to precede, or to supplement, the employment of the jigs. All possible risks of error that might arise from flexure of the long, heavy jigs are counteracted, yet the metal is distributed so as to avoid unnecessary weight. These jigs are as carefully designed, and as fully dimensioned even to their smallest details as are the engine parts themselves. They thus contrast with the foremen's hand sketches of shop tools which take the place of drawings in some establishments. Provisions are made for the correct location of the jigs on the work which they fit. Gauges check cardinal dimensions, as diameters, lengths, and some outlines. Every stage of progress is safeguarded, and the equipment is permanent for any number of repeat orders, or replacements. The heavy expense which is incurred is justified by the value of the results secured.

Although the subject of gauging in its most widely comprehensive meaning cannot be included in this series, yet occasional references to it must be made. Long before the present system of limit gauging became generally adopted and recognised, the essential method was in use, systematised in the forms of pointed rods for bores, and lengths, and of gap plate-gauges for external dimensions, and in plug, and ring, and external, and internal screw thread gauges; all being made in the shops when orders were large enough to be standardised. Sometimes the term "templet" was loosely used to designate these appliances, though the templet strictly speaking is used only for marking-off from. It is remarkable how large a volume of good work is being done with shop-made gauges. They are equally suitable for the largest as for the smaller dimensions. Allowances for tight-fits, and easy are readily made in them. They are stamped with their order numbers, dates of use, and functions. They supplement the drawings, and it is understood that the work to be tooled must be referred in the last resort to the test of the gauges rather than to drawing dimensions alone. The intimate and necessary association of these appliances is excellently illustrated in the following groups of figures which are examples from the practice of Messrs. J. Samuel White and Co., Limited, of East Cowes, Isle of Wight. The first group shown, on the present page, relates to the shafting of marine engines.

The fitting of a propeller on its shaft of large diameter by a long taper, in this case 1 in 12 accurately, throughout the length, is not a very easy task. Figs. 25 and 26 show the gauge for the shaft, and Figs. 27 and 28 that for the boss. Fig. 25 must also pass over two keys inserted in the shaft, to clear which two grooves are cut in the metal, and Fig. 27 must pass into the key ways in the boss which run parallel with the taper. Strips which correspond with the keys are fitted and screwed into grooves cut in the body of the gauge.

These two gauges are made rigidly, for if otherwise they would not retain their circular forms. The first is ribbed externally in the circular and longitudinal directions, the second has an internal rib through its axis, and metal is thickened to compensate for the removal of that cut away for the keys. Handles are necessary to lift the shaft gauge by, these being tapped into bosses about the centre (see Fig. 25). Holes at the right hand end of the gauge for the bore, Fig. 28, provide means for slinging it vertically. The gauge is chucked by its end bosses while the taper is being turned. Sheet metal gauges made to the taper would be of no value here, since they would not show any departure from a true circular form. There is a vast difference between the case of small holes and shafts, for which snap gauges are suitable, and these massive fittings. Where the fitting is that of a short shoulder, or recess, the plate forms are suitable. Examples of these kinds are shown in Figs. 29 and 30 which are used for the spigoted and socketed portions of the flanged connections of the intermediate and the propeller shafts, which ensure the concentricity of flanges and shafts. Similar gauges are used for thrust shaft connections.

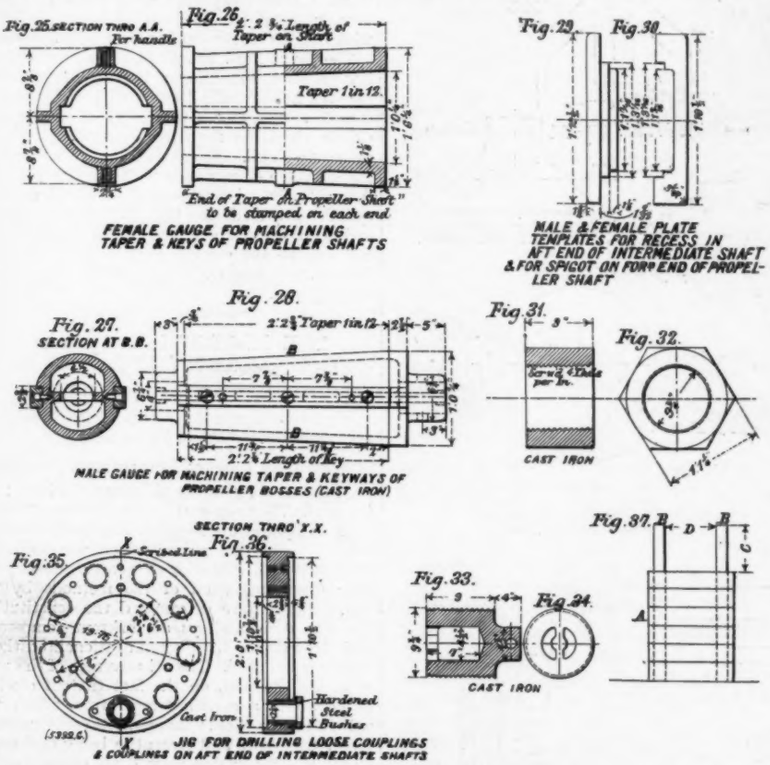


Fig. 25. SECTION THRO A.A. For handle
Fig. 26.
2' 2¾" Length of Taper on Shaft
Taper 1 in 12.
"End of Taper on Propeller Shaft" to be stamped on each end
FEMALE GAUGE FOR MACHINING TAPER & KEYS OF PROPELLER SHAFTS
Fig. 29.
Fig. 30.
MALE & FEMALE PLATE TEMPLATES FOR RECESS IN AFT END OF INTERMEDIATE SHAFT & FOR SPIGOT ON FORE END OF PROPELLER SHAFT
Fig. 27.
SECTION AT B.B.
Fig. 28.
2'2⅝" Taper 1 in 12
2'2⅝" Length of Key
MALE GAUGE FOR MACHINING TAPER & KEYWAYS OF PROPELLER BOSSES (CAST IRON)
Fig. 31.
Screwed 4 Dade per in.
CAST IRON
Fig. 32.
Fig. 35.
SECTION THRO' X.X.
Fig. 36.
Scribed Line
Cast Iron
Hardened Steel Bushes
(5352.C.)
JIG FOR DRILLING LOOSE COUPLINGS & COUPLINGS ON AFT END OF INTERMEDIATE SHAFTS
Fig. 33.
Fig. 34.
CAST IRON
Fig. 37.

Figs. 31, 32, and Figs. 33, 34 show the screw thread gauges used for testing the threads on the end of the propeller shaft, and in its nut respectively. These also are of cast iron which avoids the seizing of the gauges to the threads of shaft or nut, which would be liable to occur if they were made of steel. The gauge, Figs. 33 and 34, is suspended through a hole in an extension boss, similarly to Fig. 28.

Of the remaining illustrations on this page, Figs. 35 and 36 show jigs for drilling holes in the couplings of intermediate shafts. Varying only in dimensions are similar jigs for other shafts which it is not necessary to specify, since the features common to all are shown in Figs. 35 and 36. The body of the jig is of cast iron, lightened with a central hole. It is recessed on opposite sides—on one to receive a loose coupling, on the other to fit over the coupling on the shaft—intermediate or thrust whichever it happens to be made for. It is set alike on each by a central scribed line on the coupling and the flange. Holes—nine in number in this case—are drilled and reamered through the body of the jig to receive the hardened steel bushes which guide the drills. Two sets of bushes are fitted, one for roughing, the other for finishing, $\frac{1}{10}$th inch in diameter being left for finish. The bushes are prevented from turning by a locking plate, of gland shaped outline, which being screwed down on top of a bush holds it in firm contact on its seating. On removing it, the bushes can be readily taken out, and the other set inserted.

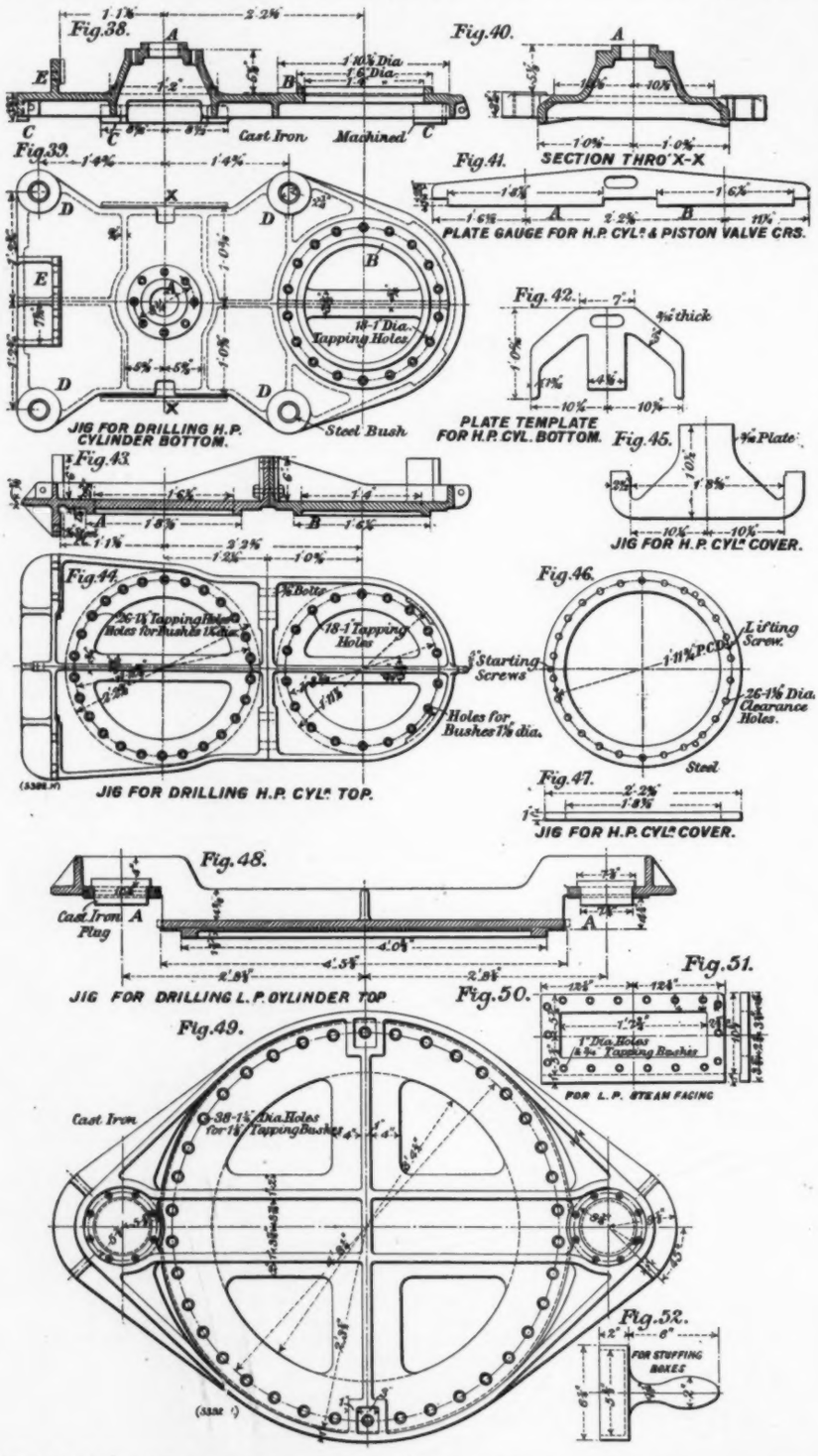
Drilling the flange and its coupling thus from the same jig, the holes come in alignment without reaming, and the bolts make a close fit therein. Here it is of interest to mention that in order to prove the accuracy of the jig and bolt holes, the firm adopts the test illustrated in Fig. 37. Jigs A are erected, some six or more being superimposed, and two bars B, B of the size of the bolts are passed down through the bolt holes. The holes are to standard size, the bars being half a thousandth below. The bars stand 12 in. above the top as at C and the distance D at the top is within half a thousandth of the accurate dimensions. For testing pitch, any one of the jigs may be turned round through a distance equal to one pitch or more, and the bars being replaced, the dimension D will measure as before. The plug gauge, Figs. 27 and 28 for shafting taper, fitted with two keys (in some cases with three), will fit the keyways in the mating gauge, Figs. 25 and 26, in whichever direction the plug gauge may be turned; the taper also bears perfectly along the whole length of the gauge.

In the jig, Figs. 35 and 36 nine holes are shown to receive tap bolts for securing the locking plates. There are other tapped holes (three in the circle) for "starting screws," the object of which is the easy relief of the jig when it has to be removed from the coupling flange, the diameter of the recesses, 1 ft. 10½ in. being made a driving fit thereon to ensure accuracy. The succeeding Figs. 38 to 47, on page 358, show jigs and templets employed by the same firm for tooling a high pressure cylinder of 1 ft. 8½ in. bore, in which is included the casing for the piston valve. A number of point or rod gauges are provided, and templets for the cylinder cover, and for the cylinder bottom, cast solidly.

Taking first the jig. Figs. 38 to 40, for drilling the cylinder bottom, this is shown as though the casting should be stood upon it, but in use it is of course turned over on the cylinder. The body is one casting, well ribbed to secure rigidity without excessive increase in weight. It is located by a spigot A, which makes a good fit in the stuffing box, and by another B that enters the bore of the piston valve chamber. The bores of the cylinder and valve chamber have already been checked by the plate gauge in Fig. 41, at 2 ft. 2⅝ in. centres—compare with the similar dimension in Fig. 38. This gauge is lifted by the hand hole. Facings C, C, are provided on the jig, Fig. 38, by which the jig is bolted to the face plate for the turning of the registers and their related parts.

Since the casting of the cylinder has a solid bottom of the sectional form of the templet in Fig. 42, no bolt holes have to be drilled there. Instead, there are four large holes D, which flank the cylinder

to receive the pillars which support it. There is a circle of eight holes for the stuffing box gland at A, and another circle of 18 for the cover of the piston valve chamber. These holes are tapping sizes for studs. All are bushed with steel $\frac{1}{16}$ in. thick.



There are also four holes at a right angle at E for drilling a facing. A hole is provided at each end, Fig. 38, to lift the jig by.

Figs. 43 and 44 show the jig for drilling the top holes in the same high pressure cylinder. The templet for the coning of the cover is seen in Fig. 45, and the jig for drilling the cover in Figs. 46 and 47. The dimensions of these figures when compared will indicate the relationships of the several parts. The jig for the cylinder top flange, Figs. 43 and 44 is cast in two parts, bolted together with closely fitting bolts. Large central areas are cut away, Fig. 44, to reduce weight, and the ribbing prevents flexure. All non-essential edges are rounded. It fits the bores by the registers A, and B (compare with the plate gauge Fig. 41), which entering the cylinder and the valve chamber ensure perfect location. The bushes are for studs, sized for tapping holes. There is a flange at right angles, Fig. 43, carrying drilling bushes for a facing. The holes in the jig for the cover, Figs. 46 and 47 are clearance holes, and are not bushed since the jig, being light is made of steel. Three holes are provided for starting screws, for the purpose mentioned in connection with Fig. 35. Seven rod or point gauges are required to complete the checking of cardinal dimensions. They test the bore, and the counterbore of the high pressure cylinder, the top and bottom recess for the liner for the piston valve bore, for the top piston valve chamber, the top recess for the bottom valve liner, and for the distance over the top and bottom cylinder faces. There are also drilling jigs for the receiver pipe flange, on the cylinder, and for the drain facing, and plate gauges for checking the shoulders in the piston valve chamber.

The jig for drilling the top flange of the low pressure cylinder is shown by Figs. 48 and 49. It makes a good fit in the counterbore, and is also located axially by two cast iron plugs A, A, which correspond with the centres of the pillars. The 38 tapping holes for the studs are bushed, as also are the smaller circles of holes for the pillar stud bolts. The central portion of the casting is lightened, leaving metal in the form of a cross. Ribbings with rounded edges are judiciously distributed.

The jig in Figs. 50 and 51 is used for drilling the low pressure steam facing. It is of cast iron, bushed for stud holes, and is located with a shoulder along one side. Fig. 52 is a plug gauge of cast iron which checks the bores for the stuffing boxes in all the cylinders—high, intermediate, and low pressure. Its diameter corresponds with that of the register A in Fig. 38. Point gauges for the low pressure cylinder are made for the diameters of the bore, and of the counterbore, and for the lengths from the top face to the column feet, and to the cylinder bottom, and from the column feet to the face of the stuffing box.

THE INSTITUTION OF NAVAL ARCHITECTS.

(Concluded from page 335.)

WE now conclude our report of the Spring meeting of the Institution of Naval Architects.

THE IRON CARBON EQUILIBRIUM DIAGRAM.

At the meeting on the afternoon of March 21 Professor H. C. H. Carpenter read a paper on "The Iron Carbon Equilibrium Diagram and its Practical Usefulness." In this paper, which we shall shortly publish in full, Professor Carpenter gave a particularly clear exposition of the methods by which metallurgists have determined the constitution of the iron carbon alloys at different temperatures, and showed how the diagram rationalised the heat treatment of steel. The effectiveness of this process depended, he said, on the fact that, if steel were raised above a certain temperature, which varied with its composition, a change in its constitution took place, the ferrite and cementite being changed into austenite. When first formed, the crystals of austenite were small, so that a large grained texture, due to long annealing at low temperatures, might, by reheating the steel till this change to austenite took place, be converted into a finely-grained structure, and this fine texture was retained when the steel was cooled again, and the austenite re-converted back into ferrite and cementite. The equilibrium diagram showed the temperature at which the change into homogeneous austenite occurred when the carbon percentage varied.

The discussion was opened by Professor W. Dalby, who said that the author had played a pioneering part in the determination of the iron-carbon equilibrium diagram. This diagram afforded a rational explanation of methods of treating steel which had been developed in practice by trial and error. It was known in the works that to obtain certain results, a certain procedure had to be followed, but this knowledge had been purely empirical until the iron-carbon diagram had been worked out. He asked the author whether carbon dissolved directly in molten iron, or whether iron carbide was first formed, which then dissolved. There was, he believed, a conflict of opinion on this point. He would also like to know whether it was possible from the micro-structure of steel to tell the temperature at which rolling was completed. He had found rails in which, on taking longitudinal sections,

the pearlite was found to lie in layers parallel to the direction of the rolling, and it was important to know whether the absence of such layers was an indication that the rail had been finished too hot.

Dr. Hatfield, who spoke next, congratulated the author on his masterly presentation of the subject. The diagram was, he added, in constant use in the steel works of Sheffield and elsewhere, and that it had become practicable to employ it in this way was largely due to the author himself, whose work had converted certain plausible assumptions into realities. As the author had pointed out, however, the diagram represented the properties of binary mixtures of pure iron with pure carbon. The introduction of other constituents would make it much more complicated. If nickel or chromium were added in proportions now not uncommon, the carbon change took place at 300 deg. to 400 deg. C. instead of at about 700 deg. On the other hand, in the case of steels containing 14 per cent. of chromium (which had some very special properties) the change in question took place at 800 deg. C., instead of at 700 deg. C., whilst with 30 per cent. of chromium, there was no change whatever. These facts indicated how extraordinarily complicated the diagram would become in the case of alloy steels. He would add that it had been definitely established that solid solutions were produced by quenching. By the operation of quenching, certain evolutions of heat were suppressed, and he had recently proved experimentally that this suppressed heat could be given out again from properly quenched steels. The author had quoted Mr. Bullen to the effect that three different kinds of annealing might be produced in the same furnace operating at a stated temperature, simply by varying the placing of the stock in the furnace. As to this, the speaker would point out that if the steel attained the same temperature, the results would be the same, no matter how it was placed in the furnace. It was, in short, not enough to take the pyrometer reading of the furnace temperature. What was required was the temperature of the steel, and, moreover, not merely of the surface, but of the interior of the mass. The importance of uniform heating on which the author had laid emphasis could not be too thoroughly pushed home. Lack of attention to this was responsible for many failures of steel in service.

Mr. Sidney Barnaby said he had examined many fractures of ship plates produced by the explosion of torpedoes. The material was a mild steel, but the fracture was invariably of the type associated with brittle materials. He had thought at first that the steel must be of bad quality, but tests showed it to be quite up to the mark. He should be glad if the author could give some explanation of this peculiar characteristic.

Sir William Smith pointed out that the author's experiments had been made with very small masses of material, with which it was much easier to secure rapid cooling than was practicable with the large masses which had to be dealt with in industry. Was there, he asked, any scale of relationship between the cooling of a small and of a large mass. The temperature gradients would necessarily be very different.

Mr. Jackson said certain difficulties arose in the workshop use of pyrometers. Admitting that it was important to finish steel as near as possible of 700 deg. C. how was this to be done? One difficulty was that the pyrometers gave the temperature of the surface, and this surface was not even steel, but scale, with a different emissivity. Again, with modern rolling mills it would be a serious matter to hold up the mill because the metal offering was not at the right temperature. Assuming uniform ingot temperatures, matters might be arranged so as to secure fairly uniform rolling conditions in the case of rails and shapes. In rolling plates, however, a difficulty arose from the spring of the rolls, which made adjustments necessary at the last pass in order to keep the thickness within the standard range. There would thus be serious difficulties in controlling the operation of a plate mill by a pyrometer. Referring to Professor Dalby's remarks he recalled a case in which a plate had been received from a railway company, which was stated to have given exceptional service. A request was made for plates of a similar character. The plate offered was examined by the usual chemical, physical and micrographic methods, which appeared to indicate that it differed in no essentials from ordinary plates. The only peculiarity was that the micrographs showed the crystals elongated in the direction of rolling, which was held to indicate that the finishing had been done at two low a temperature. It was concluded accordingly that the railway company did not know much about the matter and that the good service had been merely the result of good conditions.

Dr. Haigh observed that in a specimen of steel showing very large crystals, circulated at the meeting by the author, the crystal boundaries showed rust. He suggested that this had a bearing on the subject of corrosion, it being now the accepted view that there was an amorphous phase of the metal at the crystal boundaries.

In reply, Professor Carpenter said, in reference to Professor Dalby's query that most metallurgists held that it was carbide of iron and not carbon which dissolved in liquid iron, but this had not been definitely proved. He had also found cases such as that referred to by Professor Dalby in which the crystals had been distorted by rolling, but there was a great difficulty in getting the real history of such specimens. Dr. Hatfield's statement that the heat suppressed by the quenching of steel could be subsequently evolved was of great interest and importance. He would like to see the fractures described by Mr. Barnaby. With reference to Sir William Smith's remarks the whole difference between laboratory experiments and workshop practice lay in the time factor. Much of Dr. Hatfield's work was the transcribing of laboratory results into practice where the time taken in each operation was enormously greater. It was, of course, impossible to actually quench a very large mass of steel. With reference to the control of rolling by means of the pyrometer, Mr. Burgess, of the American Bureau of Standards, was positive as to its practicability, but he had had in view rail mills, where the difficulties due to the spring of the rolls did not come in. He had noticed the rusting referred to by Dr. Haigh and was in communication with Mr. Stead about the matter.

Stresses in Bolts and Nuts.

Mr. C. E. Stromeyer then read a paper on the "Stress Distribution in bolts and nuts." This paper was in part mathematical and the author showed that assuming the perfect elasticity of both bolts and nuts there was a concentration of stress at the neck of the bolt. There would, he showed, be an advantage in making the pitch of the threads in the nut slightly greater than the pitch in the bolts, and conversely, if the nut pitch were a little finer than that of the bolt the undesirable concentration of stress would be greatly increased. He had been able, he said, to trace certain failures of screwed rods and bolts to this defect. A series of failures had occurred of the screwed ends of the piston rods of some large gas engines. The rods were hollow, the outside diameter being 12 in. and the screwed portion was 11 in. in diameter, the pitch being four threads per inch. Several of these rods broke but in one case only was he able to measure the threads. This examination showed that the nut pitch was $\frac{1}{1000}$ in. smaller than the rod pitch. In another case some main-bearing bolts were constantly breaking for no obvious cause. At last the nut and bolt pitches were examined, and this showed that the nut pitch was $\frac{1}{1000}$ in. finer than the bolt thread. His calculations indicated that this difference of pitch would cause a stress on the bolt of 30 tons per square inch. He had examined from this point of view the principal different forms of thread, and this investigation showed that the Whitworth standards possessed a decided superiority.

The discussion was opened by Professor Dalby, who said he had recently made a large number of tests on the strength of bolts and nuts. In order to ensure that the bolt should pull through the nuts were limited to three threads. The material used was mild steel and the way in which the threads deformed and gave way was very remarkable. The nut threads turned down under the pull, and the bolt threads turned up until one could pull past the other. The diameter of the surfaces over which slipping occurred in the "pull out" was not the mean diameter of the threads, the reason being that the outer circumference of the nut threads was larger than the inner circumference of the bolt threads, so that considering a thread as a beam the nut thread was a wider beam than the bolt thread, and consequently stronger. He had also made micrographs of sections of the nut and bolt after the tests. The body of the nut showed parallel bands of ferrite with pearlite in between. In the deformed threads these bands had opened out where there was tension and closed in on the compression side.

In reply, Mr. Stromeyer observed that Professor Dalby's results had reference to cases of plastic stress. With mild steel plastic yielding of the material was possible, and this equalised the stresses. With the hard steels now being increasingly used, this relief could not be relied on, and guidance must be sought in the mathematical theory of elasticity. It was the practice to use mild steel nuts with hard steel bolts in order to get some plastic yield.

The members reassembled on Friday morning, March 22.

Reinforced Concrete Ships.

Three papers dealing with reinforced concrete ships, read by their respective authors, &c., were taken together for discussion at that meeting. The first was entitled "A Preliminary Survey of the Possibilities of Reinforced Concrete as a Material for Ship Construction," and was by Major Maurice Denny. We reproduce this paper on page 383 of our present issue. The second, on "Reinforced Concrete Vessels, by Mr. Walter Pollock, we reproduce on page 366 of our present issue. The third, on "The Design and Construction of a Self-Propelled Reinforced Concrete Sea-going Cargo Steamer Building in Great Britain, by Mr. T. G. Owens Thurston, was reproduced on page 335 *ante*.

Mr. J. Foster King said that reinforced concrete as a shipbuilding material for sea-going ships was probably the most interesting practical subject of the day to naval architects, because abnormal conditions had allowed it to pass almost at once, from tentative experiment to production on a large scale; a step rightly taken under abnormal circumstances, without waiting for the normal lifetime's experience of the results of trial and error. Major Denny's paper presented a broad review of the situation as it appeared to one having exceptional opportunities and ability to evaluate its technical aspects, and gave naval architects an early opportunity of discussing an unfamiliar method of shipbuilding, with engineers who knew the material, but were unfamiliar with shipbuilding. He agreed with Major Denny that there were important questions which would only be definitely answered by experience, but people like himself, who had expressed the opinion that existing data justified the experiment, would have more confidence in their judgment if the present discussion should resolve certain doubts. These doubts seemed to rise chiefly from the different angle at which the common problem was approached by shipbuilders and designers of land structures. One came with reasonably accurate knowledge of methods that would produce hollow girders of steel, which remained staunch and watertight at sea, under stresses which acted in different directions. The other came with fairly definite knowledge of methods that would produce from concrete, reinforced with relatively small quantities of steel, solid girders which would safely carry, on land, loads which had fixed direction. When they met, certain questions inevitably produced the statement that reinforced concrete was not "a mere juxtaposition of concrete and steel—it was a new material." Such statements suggested lack of analysis of the mechanical value of the combination, rather than hidden powers in the material, because the insertion of, say, 1 per cent. of rod steel could produce no transmutation of substance nor chemical change in structure.

As mutual understanding could only be achieved where there was mutual knowledge, the following list of properties of good shipbuilding concrete had

been compiled for criticism, from the latest information available to him:

(*a*) Good concrete was almost uniformly elastic up to the point of fracture.

(*b*) It should be watertight up to the point of fracture.

(*c*) It usually had a compressive strength about ten times as great as its tensile strength.

(*d*) It might be safely estimated to have a tensile strength of at least 300 lbs. per sq.in.

(*e*) Its tensile strength was a fair measure of its shear strength.

(*f*) Good concrete reinforced by steel rods properly arranged, and having a small area in proportion to the area of the concrete, would bind the steel under a pressure which might be over 200 lbs. per sq. in. of steel surface.

(*g*) Under the above conditions, the binding effect of concrete upon a length of rod corresponding to 30–40 diameters was equal to the tensile strength of the rod.

(*h*) Although the tensile strength of concrete was only 1 per cent., the elastic modulus of concrete was 8 per cent. of that of steel.

(*j*) Reinforcement did not alter the relationship between the above moduli.

(*k*) Reinforcement did alter the stress at which fractures occurred in the concrete, although it might not alter the stress at which fracture would occur outside the influence of its own bond upon the steel. Evidence of molecular disturbance might occur at the breaking stress of the concrete, but actual fracture was delayed until the stress was about 45 per cent. greater.

(*l*) The elastic modulus of reinforced concrete was the same as that of plain concrete—8 per cent. of that of steel.

(*m*) The strain upon the reinforcement could not therefore exceed that due to a stress of 5,400 lbs., or, say, 2½ tons, per sq. in., if the concrete was to remain unbroken.

When first required to express an opinion upon the suitability of reinforced concrete as a shipbuilding material, the structural designs were submitted to analyses which might have been a little crude, but were on safe lines, and fitted usual shipbuilding methods. On coming to close grip with designers upon details, cleavage between the points of view became more evident, and the need for agreement in method more pressing, as mutual confidence in each other's work must bear an inverse ratio to the distance which separated them. It was natural, as Major Denny said, to turn to crystallised practice as expressed in text-books and building regulations, and it was here that one seemed to find the origin of the differences, and the desirability of evidence of the suitability of their formulæ for girders other than:—

(*a*) Solid girders which were exposed to stress in one direction only, at each part of their length.

(*b*) Solid girders which might rely upon the steel reinforcement without the concrete, to resist tensile stresses up to 7 tons per sq. in., and upon both steel and concrete for compressive stresses, because cracks on one side were of no importance.

(*c*) Solid girders where the steel reinforcement did not, as a rule, exceed 1·5 per cent. of the total area of cross-section.

If it were assumed for the moment, that the foregoing correctly stated the mechanical properties of, and the limitations of present methods of calculation for reinforced concrete, then shipbuilders naturally asked whether these calculations ensured watertightness and strength in a *hollow* sea-going girder, whose top member was exposed to tensile stress throughout its whole area. One naval architect at least was startled by the assumption that sound provision for hogging stresses could be derived from calculations which considered the steel rods in the upper deck as the whole top member of the girder, that these rods might be safely stressed, in tension, to over 7 tons per sq. in.; that both steel and concrete should properly be taken into account in considering the compressive stress on the bottom; and that the resulting position of the neutral axis might be taken as true in fact.

It was obvious that under conditions of strain which were within the tensile strength of reinforced concrete, the last assumption was untrue, and that the neutral axis must be in its familiar position at the centre of gravity of the area of the section. It was also evident that the neutral axis could not pass from that position until there was a complete change in beam structure, so the assumption that the concrete might be eliminated from working considerations of tensile stress might be as dangerous as it was initially false. With the relatively small area of concrete in which most designers of ship scantlings embedded the steel tension members, it was also apparent that the concrete all round the steel would fracture when the stress on the rods approached 2½ tons per sq. in., so that watertight concrete and 7-tons stress on the steel became incompatible. When this point was urged, it was usually countered by the assertion that the method was always used in land work calculations; that the concrete did not break up, and that 15,000 lbs. stress on the steel had been successfully used in circular water tanks, yet other expert opinion (see transactions of I.C.E., 1910, Mr. de Burgh, on failure of reinforced concrete tank), declared that watertightness was unobtainable in such tanks, if the stress on the steel exceeded 12,000 lbs. per sq. in. The adherents of 15,000 lbs. as a safe stress replied that it was quite safe if there was plenty of concrete, an answer which seemed to solve the problem of securing watertightness in reinforced concrete entirely under tension, but not the reason for using indirect methods of calculation. It justified instinctive objections to massed tension rods, small concrete area, artificial section modulus, and upset calculations of tensile stress which did not include the concrete. To crystallise the foregoing in the hope of securing unity of outlook, the following appeared to be the practical and theoretical deductions which should guide reinforced design for ships:—

(*a*) A ship girder must maintain its homogeneity under ordinary working conditions in order to perform its functions as a watertight sea-going girder.

(*b*) As reinforced concrete lost homogeneity under tensile stresses which exceed the breaking stress of the concrete by 45 per cent., the designed working stress on the concrete should be less than its own tensile strength, so as to leave such a margin between ordinary and extraordinary stresses as experience had forced upon steel shipbuilders.

(*c*) As experience of reinforced concrete was derived from a ratio of steel to concrete of about 1 per cent., it seemed unreasonable to expect effective bond where it exceeded 8 per cent. This figure required confirmation from experiments upon material exposed concurrently to tension and water pressure, in order to ascertain the point where steel and concrete ceased to lend their properties to one another.

At his first contact with reinforced concrete design, Mr. King had formed and expressed the opinion in which he was now confirmed, that reinforced concrete could be used with success as a shipbuilding material within the limits of the tensile strength of the concrete, but that the true road to traverse led to the discovery of a waterproof covering having all the good qualities of concrete or more, which would not fracture until the stresses in the steel reinforcement were much higher than were at present possible.

Professor T. B. Abell stated that it was his good fortune to have been associated with Major Denny in the work on some of the concrete vessels, and in a new development from the shipbuilder's standpoint. Major Denny had made out a case for the use of ferro-concrete in ship construction, and in view of existing circumstances it was necessary to make all possible provision for relieving the demand upon tonnage. The author had also pointed out the limitations of concrete for floating structures, and had indicated the small prospect of concrete vessels successfully competing with steel vessels or earning a dividend when freights returned to normal level. The present conditions, however, justified the use of this readily-obtainable material. Doubtless nothing would revolutionise the shipping industry so much as the discovery of a metal or alloy which was lighter, stronger and more durable than steel, and as readily obtainable. For sea-going craft the use of concrete would be a retrograde step. It was essential to know the purely physical properties of the material used, and it was to this point that he wished to devote some attention. Mr. Foster King had remarked upon the need for understanding the nature of the material to be used. Mr. King had doubts, and so had the speaker in certain directions, after full inquiries. He would quote the following remark of an American engineer upon the use of concrete: "All structural materials are prepared for use before reaching the job, and can be inspected as to quality before they are incorporated in the structure." In the case of a concrete ship the material of construction was made on the spot, and actually at the time of incorporation into the hull so that the success of the structure, however good the design, depended on the thoroughness and capability of inspectors, workmen and the contractor. He agreed with Mr. Foster King that no land structure was subjected to the varying stresses to be met in the case of a ship, and the naval architect accepting responsibility for the use of the new material would have to adopt factors of safety covering elements of which he had no direct knowledge, and on which concrete engineers could not enlighten him. Mr. Foster King had made a strong point of watertightness being destroyed by reason of the tensile stress in the steel reinforcement being large enough to break the concrete, into sections, leaving a finite space for water to leak through. For that the bond between the reinforcement and the concrete must be destroyed, and there must be a definite slip between the concrete and the steel. The speaker doubted the occurrence. He believed the concrete would break up into a series of short sections of finite length, but with infinitely small interstices between the different sections. Arguing on these lines, he himself reached a doubt. One of the greatest defects of concrete was its ready abrasion by bodies sliding over the surface of the cement. So far as he could see abrasion might occur in the internal structure of a ship, Major Denny may have had the same idea in mind when referring to abrasion. If the concrete broke up into small sections distributed at intervals along the reinforcements under direct tension, when the ship was subjected to torsional movements there would be angular disturbance between those different sections. If angular motion between the different sections occurred, there must be wear or abrasion between the different blocks at the surfaces of each. From that point of view trouble might be expected, and to overcome that larger factors of safety had to be adopted than would otherwise be necessary. He thought the conjecture might be verified by a simple laboratory experiment by encasing a steel rod with concrete and putting a severe tensile stress—up to about 7 tons to 8 tons per square inch—upon it. While the bar was under tension it could also be submitted to torsion; then it could be seen whether the concrete in the interstices did break up fairly rapidly. It so happened that in the structure of a ship the bottom could be so designed that there was very little possibility of the tensile strength of the concrete being reached. In the deck, however, there was a good probability—unless a sufficient margin of safety were provided—of reaching a tensile strength which would break the concrete. He did not think the concrete would be so broken up as to imperil the watertightness of the structure.

Mr. E. O. Williams said that Major Denny stated that the tensile strength of any concrete mixture was so low that all text books and regulations agreed in placing it at zero for practical purposes, and it might be inferred from this that the tensional strength of concrete was of no practical interest in a watertight concrete structure. This was not the case. All reinforced concrete watertight structures should be designed so as to have a factor of safety against initial cracks. That was to say, when the maximum stresses come upon the material the ultimate tensile value of the concrete working in conjunction with the steel should not be exceeded. In addition to this the steel should of course be sufficient in itself to take the maximum tensile stress even if the concrete should crack. Thus, in a watertight concrete structure there were two considerations of design: (1) That the structure should have a factor of safety, however small,

against initial cracks; (2) it should have a factor of safety against final failure. It might be understood from Major Denny's statement that it would not be of any practical significance if the tensile value of the concrete were increased, but he himself saw the importance of this, for he stated that an analysis of the effect of shearing forces showed that tensile forces were to be set up. It was quite safe to say that it was the tensile value of concrete that at present fixed the limit of weight reduction of the hull, and it was for this reason that he attached much importance to a high quality cement, far in excess of British standard requirements.

Mr. Williams, continuing, said he wished to draw attention to the figures Mr. Thurston had given relating to the weight of cement, sand and stone, to give one ton of concrete. Cement, in the solid, as distinct from the loose, in which condition it contained a large percentage of voids, weighed 195 lb. per cubic foot. The figure of 0.192 tons of cement in 1 ton of concrete would thus represent 2.25 cubic feet of solid material. Sand, again, in the solid, weighed 160 lb. per cubic foot, and thus the 0.3. tons of sand would represent 4.2 cubic feet of solid material. With granite at 170 lb. per cubic foot, 0.508 tons granite would represent 6.7 cubic feet of solid material. Adding the volumes of solid cement, sand and stone, a total solid volume of 13.14 cubic feet was obtained, whereas the weights given were stated to represent 15.4 cubic feet. The difference in volume, 2.26 cubic feet, could, according to these figures, have no weight of concrete. This indicated a porosity of 15 per cent., which would be alarmingly high for watertight concrete. Mr. Thurston would find a fundamental error in these weights in that they exclude the weight of water which was not lost but combined with the cement.

Referring to Mr. Pollock's paper, Mr. Williams said it contained much with which he was in entire agreement. Mr. Pollock mentioned four methods of joining steel rods, but there was a fifth and the most economical method of attachment, namely, the lapping of bars combined with the welding of the ends. This method he proposed to employ in the near future. The efficiency of simple lapping was about 90 per cent.; for example, a 1-in. diameter bar of 35 ft. long lapping 40 diameters would have an effective length of about 31 ft. 6 in. or 90 per cent. of its length. If, however, the ends of such a bar were butt welded, and assuming that the efficiency of a welded joint was about 80 per cent., it could be shown that the resulting efficiency was 98 per cent. The welding should be done in position by a process such as the Quasi-Arc. Welding alone was certainly not, as Mr. Pollock stated, the most economical as regard weight, because the efficiency of a welded joint was seldom more than 80 per cent. of the bar, whereas that of simple overlapping was 90 per cent.

Under "disadvantages," Mr. Pollock mentioned increased cost of building and launching ways, but in this connection pointed out the difference in cost between the mechanical plant required in the two different kinds of shipyards. To launch 1,000-ton deadweight of hulls per week, 40,000*l.* of mechanical plant would be required in the steel shipyard, as against 6,000*l.* in the concrete shipyard. Mr. Pollock stated his preference for an aggregate of ¼-in. downwards. For a given proportion of cement the best concrete was that which contained the largest possible particles graded down to the smallest. For example, a one to three mixture in which the aggregate was graded from 2¼-in. downwards was 40 per cent. stronger than a similarly proportioned concrete in which the aggregate was specified not to exceed ½ in. For this reason it was advisable that the maximum sized aggregate should be as large as possible, and should be determined by the minimum distance between reinforcing bars; for instance, if bars were never less than ½-in. apart and never less than ½-in. from the centering, the maximum size aggregate should be nearly ½ in. He was not in agreement with the statement that smooth gravel should not be used as the strength of the concrete depended on the binding of the cement on to the aggregate, which was as good, if not better, in the case of smooth round pebbles. Also it was found that rounded pebbles worked better into position. It was a little dangerous to give shell thicknesses of different sized vessels, as the thickness should be determined by the shearing force on the whole ship, considered as a girder resting on a standard wave.

Mr. Pollock seemed to favour longitudinal framing. Longitudinal framing could not assist in reducing the weight of the vessel unless the longitudinal spacing of transverse bulkheads was less than the width of the vessel, in which case it paid to carry all loads longitudinally on to the bulkheads. He agreed with Mr. Pollock that the best site for a concrete shipyard was where the climate was warm and damp, and preferably protected from the prevailing winds. He strongly disagreed with any suggestion of vibrating or agitating shuttering, as this must inevitably disturb the concrete that has just passed the stage of initial set. After going into the stresses induced in the ship during launching, he was of opinion that the bending moments and shearing forces induced did not exceed the maximum occasioned by heavy seas. The sections at which the maximum launching stresses occurred were not amidships.

Mr. Bernard J. Ives said the remark in Major Denny's paper that steel embedded in concrete was completely protected from corrosion should be emphasised. It was of great importance, and if shipowners insisted on repairs being carried out in those parts of their ships specially liable to corrosion by the application of concrete before the steel had been too much consumed, repair bills would be much smaller. In concrete vessels which had come under his examination there was no likelihood of hair cracks developing into gaping cracks; where gaping cracks develop in the structure they would be found to be caused by too highly stressed steel rupturing the concrete. In regard to the watertightness of the vessel, and the treatment of the concrete by a compound, this seemed unnecessary. In connection with the question of strength the proper solution of this was to be found in combining the application of first principles and by attempting to provide the same strength as was found in corresponding elements of a steel ship. None of the papers was very definite as to limitations of size, though it was evident that the percentage of steel reinforcement to total weight of reinforced concrete rapidly increased as vessels became larger. Major Denny gave 14 per cent. for the 1,000-ton barge and 22 per cent. for a 6,000-ton vessel. From experience obtained with Lloyd's Register of Shipping in studying the problem in this and other countries, it would appear that 17 to 18 per cent. would more nearly represent a correct figure for the proper weight of steel in a non-propelling barge of 1,000 tons, while for a 6,000-ton vessel no very definite figures had been obtained. It must be remembered that there was a large variation in bending moment in the hogging and sagging conditions for a non-propelling barge of 1,000 tons deadweight which would not necessarily apply in a vessel with machinery; in fact many designs had been considered by Lloyd's Register where the sagging moment was larger than the hogging moment. Dealing with larger vessels Mr. Pollock had estimated that the amount of steel required for reinforcement would be 75 per cent. of the steel required in a steel ship for a vessel of 5,000 tons deadweight and would represent about 1,000 tons of steel reinforcement. This was at variance with Major Denny's estimate of 680 tons.

It was extremely difficult, Mr. Ives continued, to reach a conclusion as to limit of size, but civil engineers engaged in the design of large girders stated that a point was reached where the amount of steel necessary to take up the stresses was so great that reinforced concrete could be no longer usefully employed. Similarly, it was submitted that in the case of floating structures such a point would be reached, especially as the tensional strength of all parts of the structure of a reinforced concrete vessel was solely supplied by the steel. To arrive at this point, the easiest method is to work back from the larger steel vessels, which, from experience derived in actual service have had their scantlings reduced to that minimum which it would not be wise to reduce very much. Experience derived from steel vessels 375 ft. long in actual service showed that the stress on the gunwale of these vessels was about as high as the recognised authorities considered permissible. As in a concrete vessel the steel was not aided much by the concrete to take up tensional stress, the amount of steel required in a ship 375 ft. long was considerably more than 630 tons. On the whole it seemed doubtful whether it would be wise to contemplate building ferro-concrete vessels longer than 250 ft. or larger than 2,000 tons deadweight. Nothing had been brought forward in the papers as to the benefits obtained by bunching all the steel materials at the upper and lower chines, and it was a matter of opinion whether the sounder method of development would not be to spread the steel required for taking up tension and compression stresses along the upper and lower members of the girder, instead of the practice generally adopted at present. The bunching of the material did, however, permit of a sounder bond being obtained than would otherwise be the case. In regard to the use of spiral bars mentioned by Mr. Owens-Thurston, if these bars were too much twisted the steel would become unsatisfactory, and it was doubtful whether the full extent of the higher value of the yield point due to twisting could be realised, partly owing to the difficulty of accurately determining the yield point in commercial testing and partly owing to the unknown affect of alternating stresses such as would be experienced by a ship in a seaway.

Captain Waller thought account should be taken, when considering concrete ships, of the prospect of great improvement in the quality of the concrete. Never before had concrete engineers had the opportunity of making so valuable a thing as a ship's hull of concrete. He claimed that by being able to spend more money on the making of concrete, it would be practicable to reduce deadweight, but the existing cements might not be suitable for effecting this. Various cements were, however, being experimented with. The demand had been created for a supercement, and he was expecting a report on a cement —a mixture of one part cement and three parts Leighton Buzzard sand—which after two days produced a tensile specimen giving 1,038 lb. to the square inch in tension. With the improvement in concrete foreshadowed, he believed that a concrete hull would be a far better hull for many ships than a steel hull. He would take the "Mauretania" as an example of vibration, which, in the second-class quarters, was appalling. If the vibration was as great in the case of a concrete ship, the latter would have no prospect. But by the analogy of ferro-concrete structures in factories, the vibration should tend to disappear in the case of concrete ships. In these ships the hull could be kept cool in the tropics. It was quite possible that concrete ships, as compared with steel ships, would be somewhat slower.

Mr. S. W. Barnaby inquired of Major Denny whether the latter considered that great ranges of temperature would have any effect on the bond in the case of the deck. The deck was exposed not to the sea, but to the sun, and with very cold weather would the grip of the iron be reduced?

Major Denny, answering the question just raised, said he could only speak with diffidence on that point, which was one lying more within the province of the concrete engineer, but judging from experience with piles and similar structures which had been exposed to very great differences of temperature, summer and winter, and exposed also to alternate wetting and drying in both seasons, the deterioration of the structure by reason of the conditions named did not, by any means, appear to be marked. Therefore, he had not considered the point.

As to the general comments on his paper, he had little to say. He had lately learnt much on the technical side concerning the strength of ships. The circumstance that Mr. Williams was about to make experiments with hollow girders, and the reference made by Captain Waller to a somewhat astonishing cement, indicated that the concrete engineer was, to some extent, overhauling his profession. During the next three months, when a great deal of information on the details of the programme of concrete construction would be available, it would be seen whether the ideas put forward were sound or otherwise. He had no wish to prophesy, but he did not think there would

be cause for disappointment in relation to the service results of the present programme of ships.

Mr. W. Pollock said he would reply in writing to the various points raised in the discussion.

Mr. T. G. Owens Thurston expressed his appreciation of the way in which his paper had been received. In connection with Mr. Williams' remarks as to the weight of ingredients in a cubic yard of concrete referred to in his (Mr. Thurston's) paper, this was really a matter for the ferro-concrete engineers who supplied the data. This matter, however, would be looked into, and if an error had crept in, which was quite likely owing to the haste in which the paper had been prepared, this would be rectified before the final printing of the transactions. He was quite sure that Mr. Williams would be glad to know that whether the figures given were right or wrong, they could have no possible influence on the final completion of the vessel, as the weights assumed in the calculations for the finished ship were not those obtained from any estimates, but from the weighed-in quantities on the actual work itself.

On the motion of the chairman, the authors were awarded a hearty vote of thanks for their contributions.

STRESSES IN SHIP STRUCTURES.

At the meeting on Friday afternoon a paper by Mr. A. M. Robb, B.Sc., was read, entitled "An Investigation of the Shearing Force and Bending Moment Acting on the Structure of a Ship, including Dynamic Effects." We shall publish this in full in a later issue.

In this paper the author works out the stresses on a 6,200-ton cargo-and-passenger ship. The assumptions usually made in such calculations are that the ship is supported either on the crest of a wave equal to its own length or on the trough of the wave. The author has worked out, in addition, the results when the crest of the wave is at different distances from the midship section. He finds that save for sections close to the ends of the ship the stresses are always less when the wave is thus displaced than those calculated on the standard assumptions. He also finds that the stresses are reduced considerably on passing from the midship section towards the ends, and he suggests that further advantage of this fact might be taken in fixing the scantlings of the ship. The author considers also the variation in these stresses, which arise from the accelerations of the ship as it heaves out of or into the waves. The important conclusion is reached that the effects of these accelerations are in general sufficiently provided for if the hull is proportioned to withstand the statical hogging moments as determined on the usual assumption, but cross-Channel steamers and fast liners are exceptions to this rule. The author also determines the effect of the angular accelerations due to pitching. He calls attention to the lack of adequate data as to the actual accelerations experienced in practice and suggests that experiments should be made to supply the deficiency.

The discussion was opened by Sir John Biles, who said that the introduction of the integraph had greatly facilitated Mr. Robb's investigations. He pointed out that Sir E. J. Reed was the first to attempt to calculate the stresses produced on a ship's structure, both when resting in still water and when exposed to waves. Mr. Robb had completed this work by taking into account other relative positions of ship and wave, and also the effect of the accelerations which arise in heaving and pitching. The author's conclusion that the additional factors included in his investigations did not materially effect the maximum stresses as calculated in the ordinary way, was important, as it indicated that as built ships had an excess of strength at sections distant from the midship section. The point thus raised was a matter for the consideration of the registration societies.

Professor Welch, who followed, said that the effects of heaving and pitching had been pretty exhaustively studied at the Armstrong College, but the author had gone one stage further in discussing the effect of different relative positions of the ship and wave. The speaker, in his own work, had assumed that it was enough to put either the crest or the trough amidships, and this seemed to be now definitely established by the author's work. The broad conclusion arrived at, by the work done at Armstrong College, confirmed the author's results that heaving into a wave would result in greater bending moments than those found in the statical condition. Nevertheless the ordinary methods of computation in which accelerations were neglected did seem to give results very closely in accord with the maximum shears and moments produced under any conditions. He agreed with Sir John Biles that the author's results might justify them in reducing scantlings slightly more rapidly on passing from the midship section than had hitherto been admitted.

Mr. Foster King said that the author's paper would afford valuable guidance for the registration societies. He was inclined to think though that if double the factor of safety were allowed for dynamic as compared with static stresses, that the ordinary shipbuilding practice of carrying the material well forward and aft of the midship section would prove to be justified.

AIR SUPPLY TO BOILER ROOMS.

Mr. R. W. Allen, C.B.E., then read a paper on "Air Supply to Boiler Rooms." The paper drew attention to the great losses of power which result when the air trunks to and from the fan are badly designed. The importance of avoiding sharp corners and sudden enlargements and contractions of area were emphasised. It was also pointed out that the inlet cowls were often very badly arranged on the upper deck, being sheltered by structures which prevent the free access of air to them. His firm had further found that considerable savings might be affected by designing the inlets to these cowls in closer accord with scientific principles. It was also important to suppress any eddies in the air as it entered the fan, and a form of screen which had proved very successful in this regard was described. It was further shown that when two fans, side by side, were delivering air there might be a wasteful interference of the air currents which could be suppressed by the use of suitable deflectors. We shall publish the paper in full in a future issue.

The discussion was opened by Mr. Harold Yarrow, who said that the Institution was indebted to the author for bringing before them the results of many costly experiments and of the practical experience of his firm. Some seven years ago the speaker's own firm had come to the conclusion that turbine-driven fans were the most suitable for use on destroyers, and they had made arrangements accordingly with the Terry Steam Turbine Company. These turbine-driven fans had proved most satisfactory in service. The spindle was vertical, and the fan was fitted immediately under the main deck, where it was well out of the way. The access of air was most direct and certain losses were thus avoided. Further, the fan being high up above the boiler-room floor, the air delivered was thoroughly well distributed before it reached the furnaces. The noise had been urged as an objection, but this had not been found to be of any importance from a military point of view. The speed being high the fan was compact, and there was probably some advantage in the fact that this speed was constant throughout each revolution, which was not the case with a reciprocating engine drive.

Mr. Hamilton Gibson, who spoke next, said that he thought his own firm—Messrs. Cammell Laird and Co.—might claim to have been amongst the first to realise the importance of the complete Allen scheme for air supply, which was based on a new and thorough examination of the whole question. It had, of course, been long common knowledge that the air passages should be free and unobstructed, but this knowledge had been disregarded in practice. Of course, in many cases the ideal had to give way to other requirements, and a compromise was necessary. The author's rules and tables would be of great service. His statement that considerable power was required for the air supply was true, but after all it was only a small percentage of the total propelling power. The real advantage was, therefore, less in the power saved than in the economy of space and weight, not only in the fans and engines but also in the cowls and trunks. The latter were not required on smaller boats, such as destroyers with only one deck, and the problem was thus simpler with them. He had known a case in which there was a large leakage of air from the fan back into the air suction which had been remedied by fitting inlet rings. This alteration made all the difference between an absolute failure and a successful trial. In running groups of fans it was important that all should run at the same speed. It would not do to have one delivering air at 2½ in. and the others at 3½ in. water gauge. His firm had accordingly introduced the plan of controlling the speed of the whole set of fan engines by a master governor, and this was now almost universal practice. He asked if there would be any advantage in arranging the author's streamline screens with radial instead of horizontal slats, so as to secure a uniformity of conditions in the flow of air to every part of the fan.

Mr. W. H. Allen said that twenty-four years ago Mr. Howden had read a paper on forced draught, but he was before his time, and his propositions were held to be wrong. Nevertheless, Mr. Howden lived to see his proposals adopted by all yards. The speaker had himself begun to study the subject at about the same time. Later on, Sir John Durston, who was dissatisfied with his colleagues' views on this question, asked the speaker's firm to carry out further experiments. These extended over some months, and were the foundation of present practice. He thought he might fairly claim it to be a great achievement to have constructed satisfactory ventilating plant in which the fan periphery ran at a speed of 3 miles a minute and was driven by a reciprocating engine running at 600 r.p.m. and developing 150 h.p. It was, however, little good to put such a plant in ships if the air trunks and accessories were badly installed. This matter was particularly important now that oil fuel was being used.

In reply, Mr. R. W. Allen said he had been interested in Mr. Yarrow's remarks as to the success of turbine-driven fans. Before the war Germany, Austria and the United States had all adopted turbine-driven fans, but he believed this was largely due to the fact that reliable high-speed reciprocating engines were not built in those countries. Had it not been for this he doubted whether the turbine would have come into favour quite so soon. He believed, however, that the tendency towards turbines would continue. There was a fashion in such things, and the change from reciprocating engines to direct turbine drives and from the latter to geared turbine drives for the main propelling machinery was likely to be imitated in the case of the auxiliaries. He was obliged to Mr. Gibson for his remarks, and agreed that Messrs. Cammell Laird and Co. had been amongst the first to recognise the improvements made by the speaker's firm in the matter of air supply. Shipbuilders had so many other matters to attend to that they did not always spend the time and thought on the design of the air trunks that was desirable. Practice differed from yard to yard, but there seemed no good reason why standard systems should not be adopted for each class of ship. Admittedly a compromise was necessary, but the basis of this compromise should be the theoretical ideal. He had not tried radial slots, but up to the present they had got their best results with the system illustrated in his paper.

A vote of thanks to the President terminated a most successful meeting.

MAGNESITE IN THE UNITED STATES.—According to the estimates of the U.S. Geological Survey, says *The Iron Age*, New York, the production of magnesite in California in 1917 exceeded that of all former years, being estimated at 215,000 tons. This quantity and the magnesite produced in the recently discovered field in Stevens County, Wash., estimated by the Survey at close upon 100,000 tons, makes an output of 315,000 tons in 1917, or 15,000 tons more than the normal domestic demand. In view of the great increase in production made in California and of the fact that some of the large properties in Washington were only partly developed at the close of 1917, it is believed that the domestic industry hereafter will be able not only to supply the home demand, but may be able to produce a surplus for the Allies. Until 1915 the United States produced only about 10,000 tons of magnesite annually, although it used 300,000 tons. The imported material came from Austria, Hungary and Greece.

TRIPLE-EXPANSION PUMPING ENGINES FOR THE LONDON COUNTY COUNCIL.

CONSTRUCTED BY MESSRS. FULLERTON, HODGART AND BARCLAY, LTD., ENGINEERS, PAISLEY, TO THE DESIGNS OF MR. H. M. ROUNTHWAITE, MECHANICAL ENGINEER, L.C.C.

(*For Description, see Page* 363.)

Fig. 10.

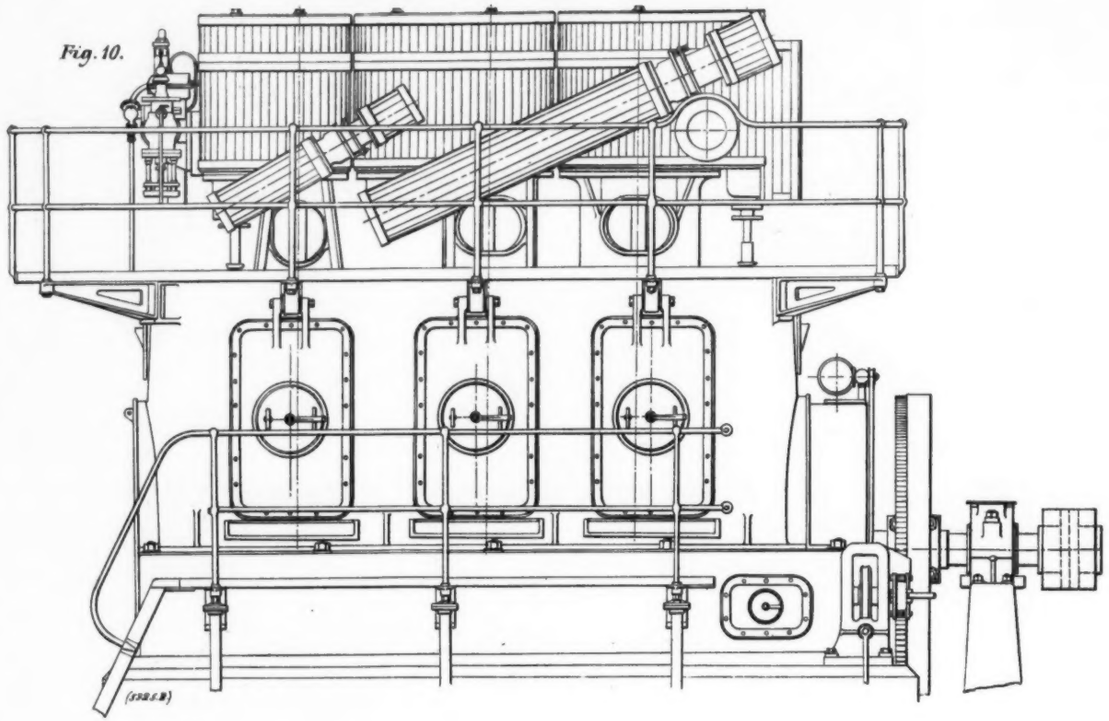


Fig. 18.

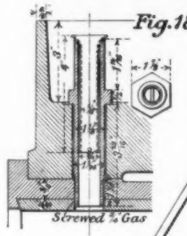


Fig. 17.

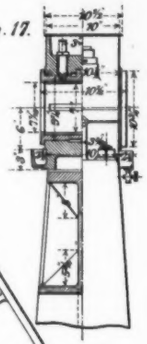


Fig. 15.

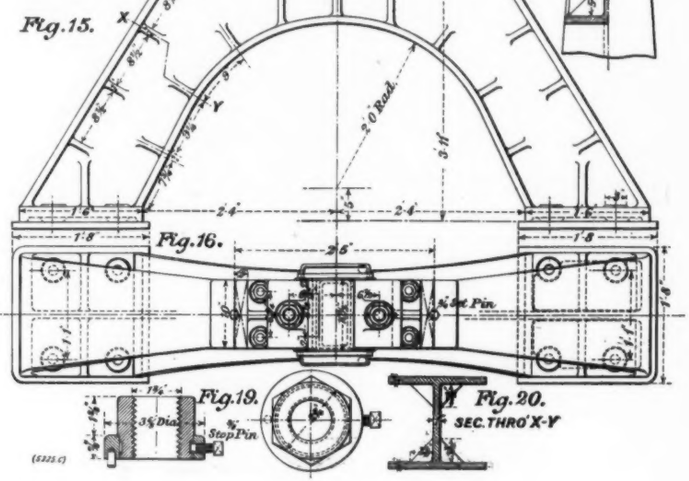


Fig. 16.

Fig. 19.

Fig. 20.
SEC. THRO' X-Y

Fig. 11.

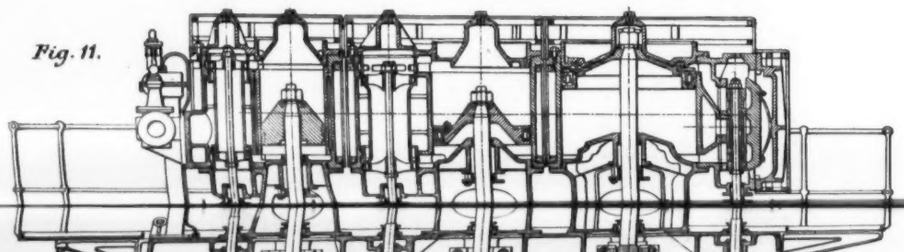
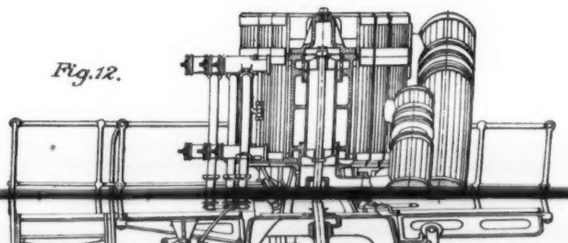


Fig. 12.



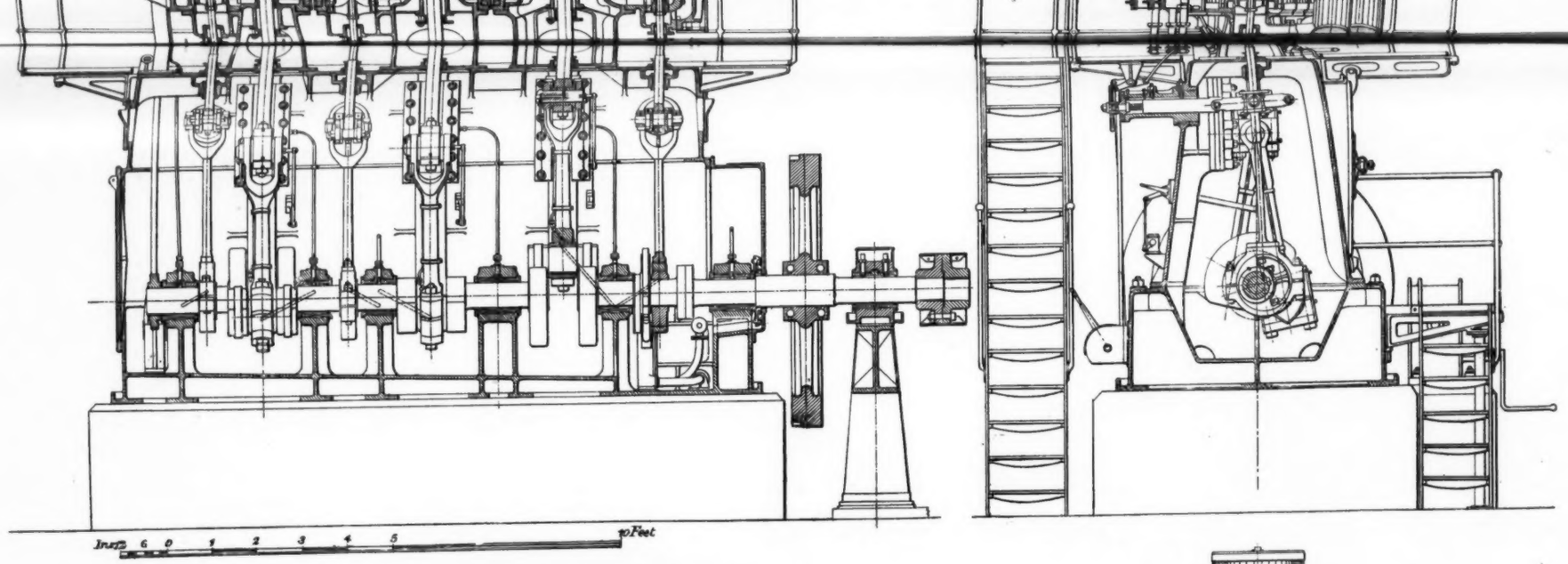


Fig. 13.

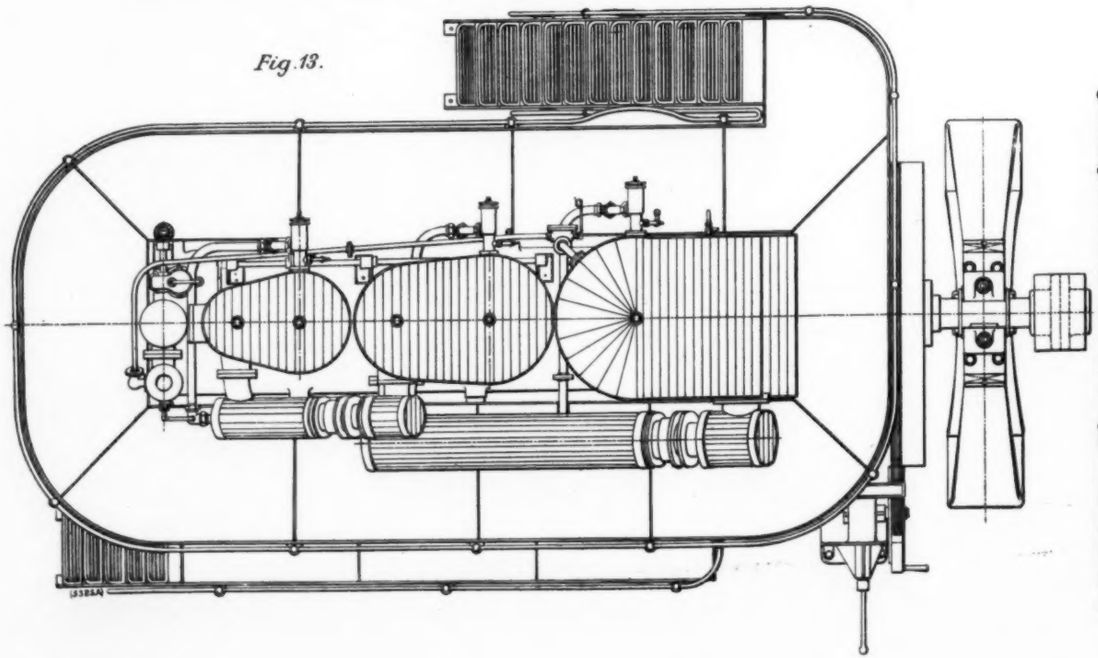
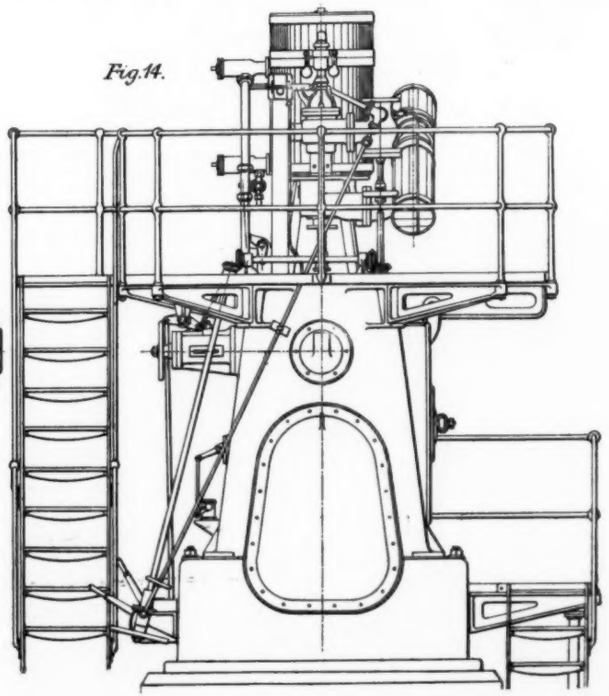


Fig. 14.



TRIPLE-EXPANSION PUMPING ENGINES FOR THE LONDON COUNTY COUNCIL.

We illustrate on this page and on pages 364, 365, and 372 centrifugal pumping plant recently installed at one of the London County Council sewage-pumping stations to supplement the reciprocating pumping engines erected there a good many years ago. The general character of these old engines is indicated in the diagrammatic sketch reproduced in Fig. 1, subjoined. The new pumps are primarily intended to deal with storm water, but are also to be used for pumping the sewage under normal conditions. It was necessary, accordingly, that the pumps should be capable of working effectively through a large range of heads. As installed the plant consists of four 38-in. centrifugal pumps, each coupled to a three-crank triple-expansion engine. These engines are fully enclosed, and operate with forced lubrication.

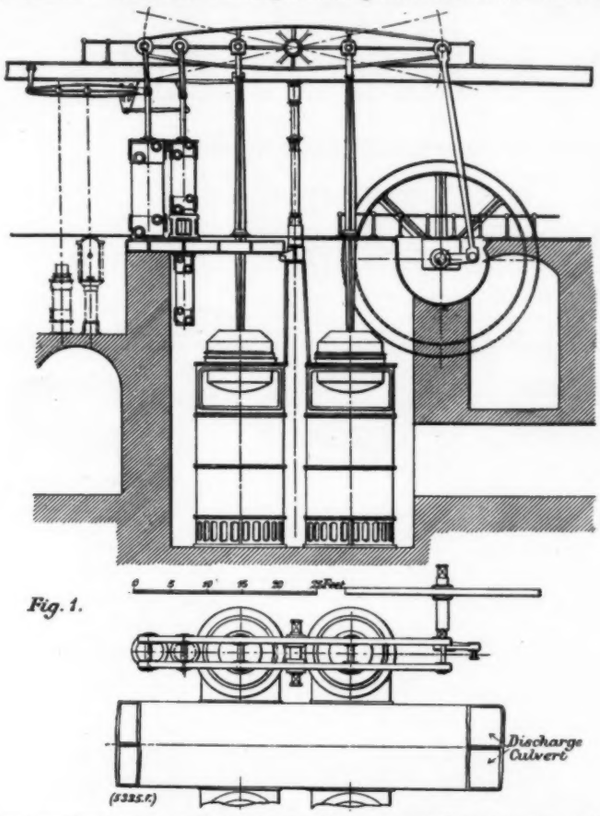


Fig. 1.

L.C.C. Pumping Plant.—Comparison of Beam Pumping Engines with New Centrifugal Pumping Sets.

Type of Pumping Set.	Overall. Length.	Overall. Width.	Length × Width. Actual.	Length × Width. Relative.	Comparative Heights of Sets.	Diameters and Strokes of Steam Cylinders.	Normal Revolutions per Minute.	No., Description and Size of Pumps.	Weight Pumped per Minute.	Normal Lift.
	ft.	ft.	sq. ft.		ft.				tons.	ft.
Beam pumping engine	70	19	1,330	3.5	60	H.P., 19 in. by 6 ft. 10½ in. I.P., 32 in. by 6 ft. 10½ in. L.P., 44 in. by 9 ft.	10 (about)	2 S. A. Ram pumps, 108 in. diameter, 3 ft. 4½ in. stroke	110	20
Centrifugal pumping set	29	13	377	1.0	22½	H.P., 15 in. by 1 ft. 6 in. I.P., 23 in. by 1 ft. 6 in. L.P., 32 in. by 1 ft. 6 in.	160 (about)	1 centl. with 38 in. suction and delivery branches	120	21

The general lay-out of the new station is well shown in Figs. 2 and 3, page 364. The old reciprocating sets naturally occupied a good deal of room, and, as indicated in the annexed table, the new installation shows to great advantage in this regard. Indeed the new engine-room affords space for four more sets of the same size should these be required in the future.

To supply steam for the new plant the boiler-house was lengthened, and the former boiler capacity of the station augmented by the addition of four more Lancashire boilers, each 29 ft. long by 8 ft. in diameter. These are designed to work at 150 lb. pressure, and are fitted with Ferguson superheaters of sufficient capacity to ensure the provision of dry steam at the stop valve of the most distant engine, in spite of the very considerable length of the main steam pipe.

Previous to the installation of the new pumps, the supply of condensing water was secured by filling certain ponds from the river at high tide. From these ponds the supply for the condensers was taken, and returned directly from the condenser to the river. As it was impracticable on the site available to increase the impounding capacity of the ponds sufficiently to maintain this method of working, cooling-jet apparatus was arranged over the existing ponds so that the water could be used repeatedly and no additional pondage was consequently required.

The general character of the new engine-room is clearly shown in Figs. 2 to 4, page 364, and in Fig. 8, page 372. A small direct-driven centrifugal pump has been provided, as indicated to the right in Fig. 2, for draining the suction culvert when access is required. The condensers, as shown in the plan, Fig. 3, stand on a floor 3 ft. 6 in. higher than the engines, and are fitted with independently-driven air and circulating pumps. Two condensers are at present in place, but as will be seen there is ample room for two more should the pumping capacity of the station be increased at some later date.

The pumps, as shown in Figs. 5, 6 and 7, are fitted with sluice valves on their discharge branches, and these sluices can be opened or closed either from the upper gallery by hand, or, as indicated in Figs. 5 and 6, by hydraulic gear from the engine-room floor by means of the chain shown. The pumps were designed by Messrs. Boving and Co.

The engines and condensers were built by Messrs. Fullerton, Hodgart and Barclay, Limited, of Paisley, to the designs of Mr. H. M. Rounthwaite, mechanical engineer to the London County Council, and a good idea of their general design is given by Fig. 9, page 372, which is reproduced from a photograph taken after the final erection of the engines, whilst Figs. 10 to 14, on Plate XXXVI, and Figs. 21, 22, and 23, page 365, show details of their construction. The cylinders are 15 in., 23 in. and 32 in. in diameter by 18-in. stroke, and at the normal running speed of 160 r.p.m. the engines develop 340 h.p. Though the average head against which the pump works is 21 ft., it may at times be as much as 30 ft., and hence the specification required that the engines should work satisfactorily at horse-powers ranging from 275 h.p. up to 400 h.p., and at speeds of 140 r.p.m. to 172 r.p.m. In order to ensure a good distribution of the load over all three cylinders under these varying conditions the valve gear for each cylinder has been made separately adjustable. Thus the connection between the eccentrics and the valve spindles is not direct, but each valve is driven through the intermediary of a link, the position of which can be varied by the hand wheel and screw best shown in Fig. 12, Plate XXXVI. In this way the valve travel can be varied within a wide range, thus making it possible to adjust to practical equality the powers developed in each cylinder whatever the head on the pumps.

Piston valves are used on the high-pressure and intermediate-pressure cylinders, whilst a flat valve balanced on the plan introduced by the late Mr. Martin, of Flushing, is used for the low-pressure cylinder. The high-pressure cylinder and the H.P. and I.P. valve chests have renewable liners, and the low-pressure cylinder has a renewable port face of hard cast-iron. Allowance has been made throughout for reboring the cylinders and valve chests should this become necessary at some future date. The lagging is unusually complete. It consists of asbestos millboard clad with teak, and covers not only the cylinder and valve-chest walls, but all flanges. Balance weights of steel are fitted to the high-pressure and the low-pressure cranks, and are so disposed so as to give as effective a balance as is possible with but two weights. These weights are held in position by wrought-iron straps. The governor is driven by spiral gearing from the high-pressure end of the crankshaft.

The cylinder stuffing-boxes stand well clear of the crank casing, and light stuffing-boxes below them prevent any possibility of an escape of water from the glands into the crank chamber. The high pressure and intermediate glands have metallic packings. The piston-rods and the connecting rod gudgeons are of mild steel specified to have an ultimate tensile strength of 38 tons to 42 tons per square inch. The brasses are of phosphor-bronze, lined with white metal. Forced lubrication is fitted throughout. The spent oil drops to the bottom of the crank chamber, the base of which slopes from left to right and drains down this to a sump at the right-hand end of the chamber, as shown in Fig. 22, where the oil pumps are situated as shown in Fig. 21. An oil flirt is provided on the shaft near its exit from the crank chamber, to prevent any creeping of the oil along the shaft to the exterior.

As shown in Fig. 10, the flywheel is carried on a separate length of shafting, one end of which is supported in a bearing included within the crank chamber and the other on an independent bracket, which is illustrated in detail in Figs. 15 to 20, Plate XXXVI.

According to the terms of the contract each engine was to develop 400 h.p. when running at about 172 r.p.m., and the steam consumption under these conditions was not to exceed 16½ lb. per indicated horse-power hour, inclusive of that taken for driving the air and circulating pumps. The trial was specified to be run with a supply at the stop valve, of dry but not superheated steam at a pressure of 155 lb. absolute, and on the official tests the figure 15.9 lb. per horse-power hour was obtained.

Each of the four sewage pumps is capable of delivering up to 130 tons per minute (29,000 gallons); they are of the shrouded-impeller type. As already mentioned, they were designed by Messrs. Boving. They are fitted with steam ejectors of the Penberthy type for exhausting the air before starting. When one pump has been exhausted (requiring, say, 8 minutes) and started, the others can, of course, be charged from the discharge culvert. The discharge pipe from each pump (referred to above) is fitted with a hydraulically-operated sluice valve, the hydraulic water for which is laid on all over the station and operates penstocks, filth cages, ash hoists, &c., and is applied to a small three-cylinder engine attached to the valve casing.

(To be continued.)

The Cleaning of Railway Carriages.—For cleaning the cloth-covered parts of railway carriages, says *Le Genie Civil*, the Paris-Orléans Railway Company uses an electrically-driven brush and a vacuum cleaner. The dust is first removed by the vacuum cleaner, then the cloth is impregnated with mineral spirit by hand by means of a sponge, the circular brush being then used. Finally, the cloth is sponged over with water and dried by means of the vacuum cleaner.

TRIPLE-EXPANSION PUMPING ENGINES FOR THE LONDON COUNTY COUNCIL.

CONSTRUCTED BY MESSRS. FULLERTON, HODGART AND BARCLAY, LTD., PAISLEY, TO THE DESIGNS OF MR. H. M. ROUNTHWAITE.

(*For Description, see Page* 363.)

Fig. 2.

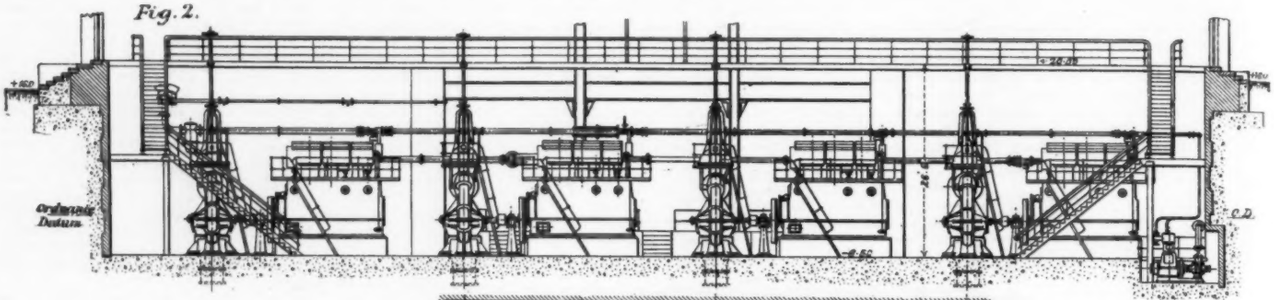


Fig. 3.

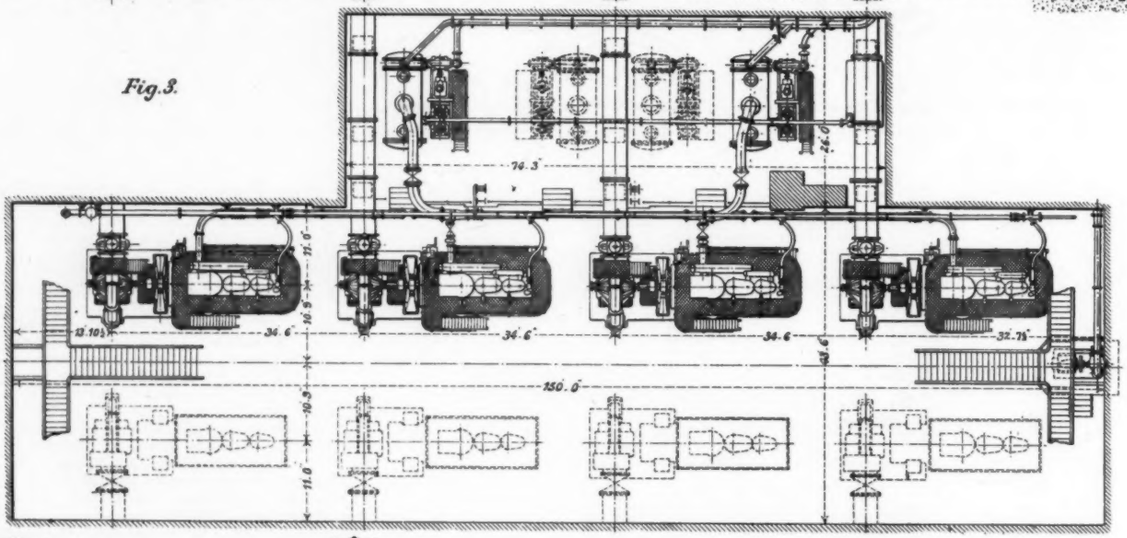


Fig. 5.

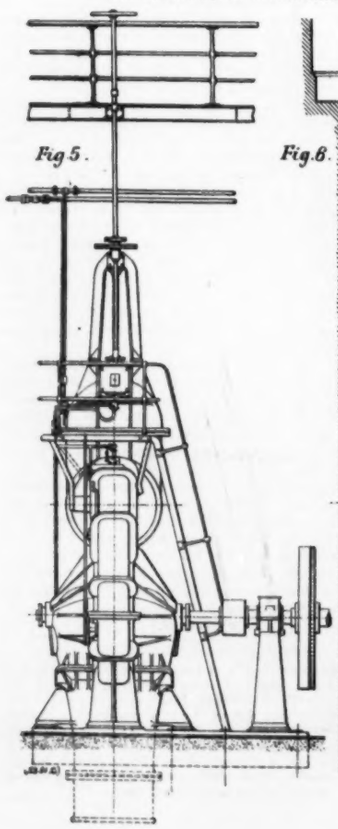


Fig. 6.

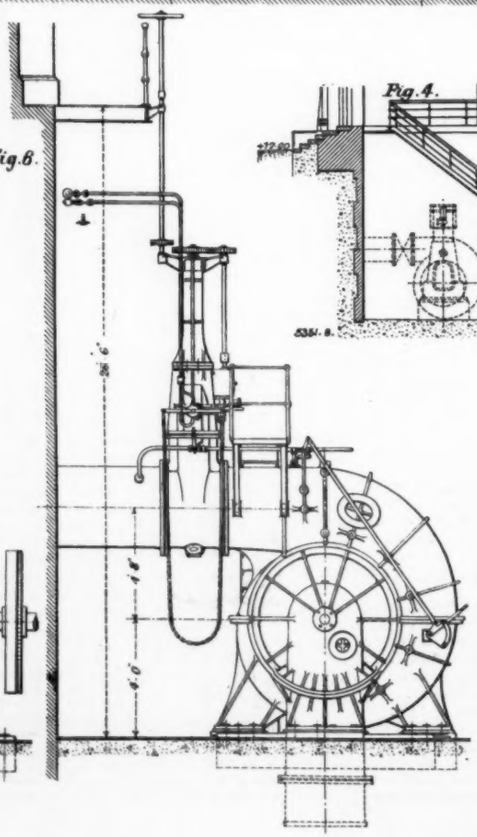


Fig. 4.

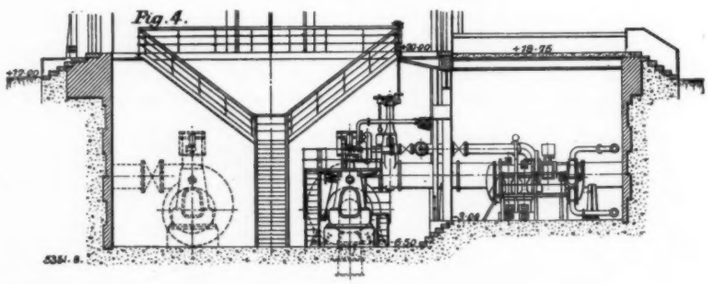
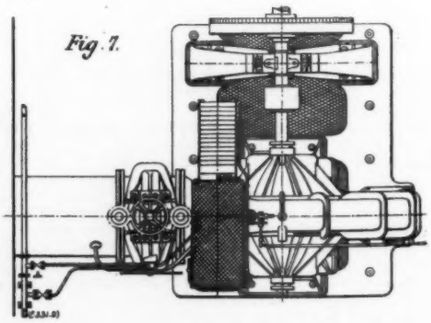


Fig. 7.



TRIPLE-EXPANSION PUMPING ENGINES FOR THE LONDON COUNTY COUNCIL.

CONSTRUCTED BY MESSRS. FULLERTON, HODGART AND BARCLAY, LTD., ENGINEERS, PAISLEY, TO THE DESIGNS OF MR. H. M. ROUNTHWAITE, MECHANICAL ENGINEER, L.C.C.

(*For Description, see Page* 363.)

Fig. 21.

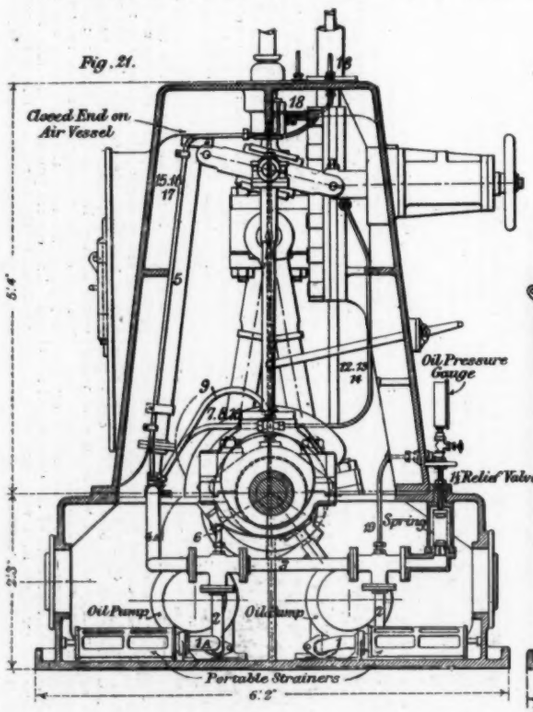


Fig. 22.

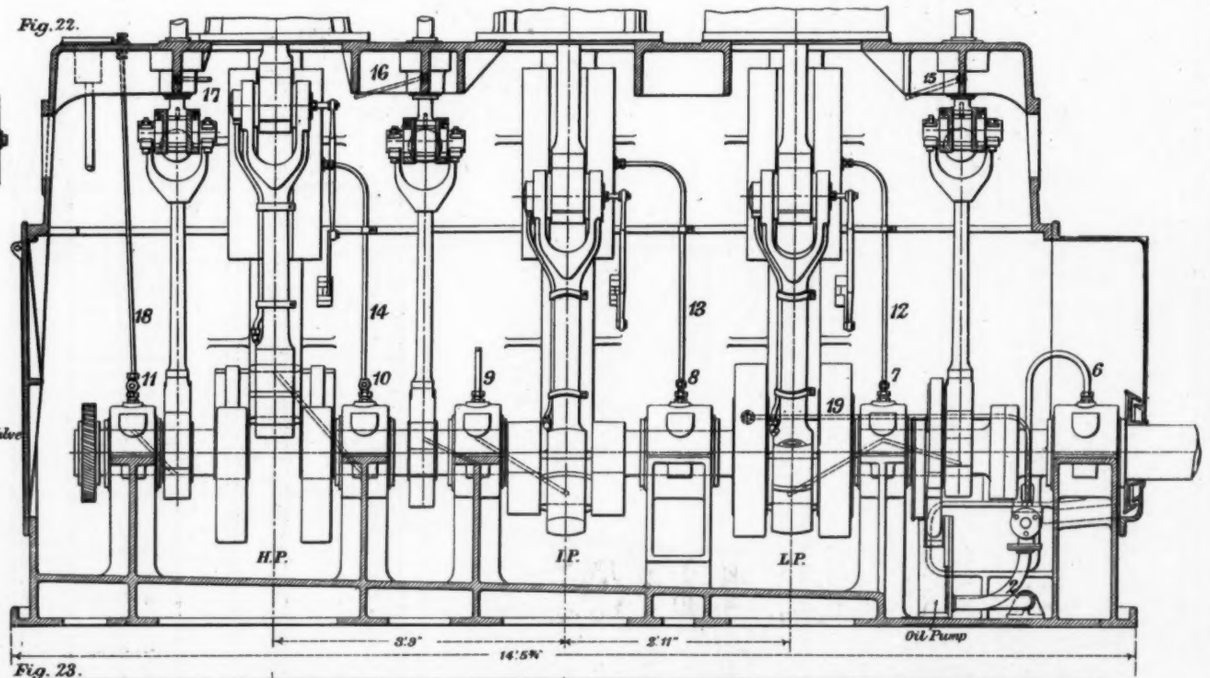
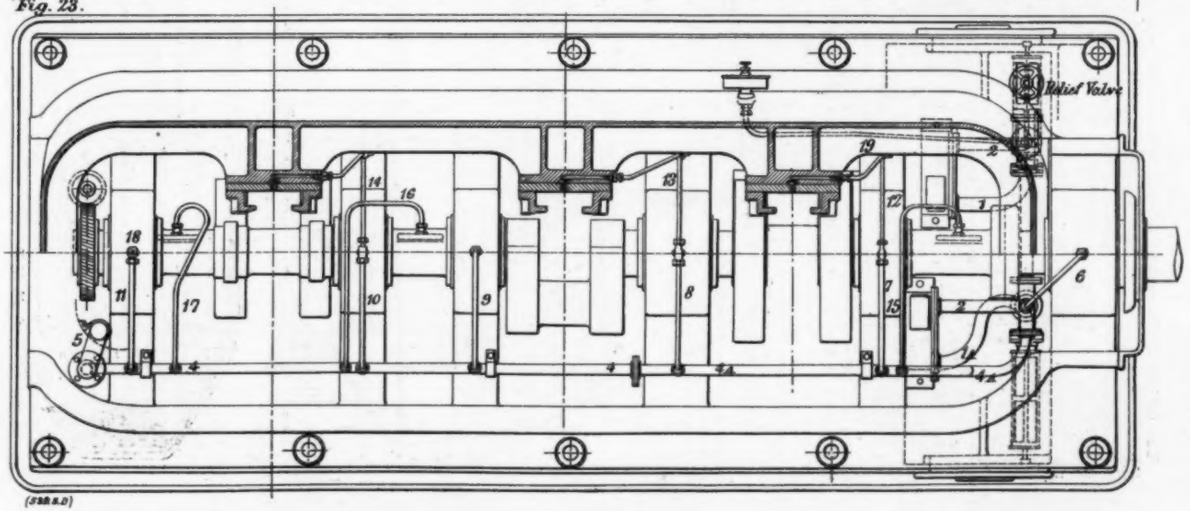


Fig. 23.



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PARTICULARS OF PUMPING ENGINES.

Diameter of cylinders—high pressure	15 in.
Diameter of cylinders—intermediate pressure ...	23 in.
Diameter of cylinders—low pressure	32 in.
Stroke	18 in.
Revolutions per minute—normal	160
Indicated horse-power—normal	340
Average head against which pump works ...	21 ft.
Duty of pumps	130 tons per minute

REINFORCED CONCRETE VESSELS.*

By MR. WALTER POLLOCK.

THE subject of the present paper is one of great interest and importance, but on which there is a great dearth of exact knowledge. The author does not pose as an authority, but having spent some time studying the subject from a practical standpoint, hopes that members will derive some benefit from his notes, opinions, and experience, as also from the views put forward by others during discussion. The development of reinforced concrete vessels is in a very embryonic stage and seagoing experience is practically nil. The war situation brings the question before shipowners and shipbuilders as one not to be lightly dismissed, and has resulted in close co-operation of naval architects with experts in concrete structures, to produce the best designs that present knowledge permits. Three principal causes have been at work to direct attention to this subject, viz.: (1) The imperative need of economy in steel and timber owing to vast calls on these materials for numerous war munitions and equipment; (2) the urgent necessity to use a minimum amount of skilled labour in home industries; and (3) the insufficient number of small mercantile vessels such as coasters, tugs and lighters that have been built owing to the prior claim of naval vessels. It is only fair to say that the present programme of construction of reinforced concrete vessels would not have been possible had it not been for the pioneer work which established its possibilities before the autumn of 1917.

Historical.—The first reinforced concrete boat was a small rowing boat built and patented by M. Lambot, of Carces, France, in 1849. Apparently nothing further was done until 1887, when the sloop De Zeemeuw was built in Holland; it has been in constant service since, including work among ice, and is reported to be still in good condition. In 1896 Messrs. C. Gabellini, of Rome, made a rowing boat by plastering cement and sand on both sides of a steel wire mesh making a total thickness of 1 in. In 1905 this same firm constructed the lighter Liguria and, following its seagoing trials, several other cargo vessels. It is stated that there are now in Italy vessels and pontoons which have been tested under severe loading to the satisfaction of Italian naval officers. In 1909 a barge or lighter carrying 220 tons was built in Frankfort-on-Main for the transport of gravel. In 1910 a concrete scow was built in San Francisco 100 ft. by 30 ft. by 7 ft., and of 525 tons carrying capacity. In 1911 concrete barges were built on the Panama Canal, 64 ft. long by 24 ft. wide, with a depth of 5 ft. 6 in. In the same year a barge was built by Mr. O. F. Lackey, of Baltimore, length 50 ft., breadth 22 ft., and depth 7 ft., carrying 86 tons of cargo. As a result of the experience with this barge a concrete scow of 500 tons was built in 1912 by the First Concrete Scow Construction Company, of Baltimore.

The Sand Witch, the hull of a river dredger, was built on the Thames in 1910, and a pumping lighter was built for the Manchester Ship Canal in 1912, dimensions 100 ft. by 28 ft. by 8 ft. 6 in. The Namsenfjord, a coaster of 200 tons deadweight, was built by the Fougner Company, of Norway, in 1917. The Beton I, another 200-ton vessel, was launched keel uppermost in August, 1917, by the Porsgrunds Company, Norway. A 5,000-ton deadweight capacity vessel is now being built in San Francisco, length 320 ft., breadth 45 ft., depth moulded 31 ft., draught 24 ft., and is to be fitted with steam machinery of 1,750 h.p.

Limitations.—For river craft, pontoons, floating dry docks, floating piers, &c., reinforced concrete construction will probably develop and become a permanent industry. For river and harbour lighters, tugs and coasting vessels, this form of construction will, if all the present experimental vessels are successful, probably remain a recognised form of construction for some years to come. Steel vessels may come back to their own as soon as freights are low and the competition keen. For larger vessels up to, say, 2,000 tons deadweight capacity, reinforced concrete will no doubt prove a practical and commercial proposition for a few years. Particulars are given above of a vessel of 5,000 tons being constructed in San Francisco, but it is difficult to see the advantage of using concrete in this case, as the amount of steel required for reinforcement, &c., will probably amount to 75 per cent. of that of a steel ship of the same deadweight capacity. The gain, together with the saving in skilled labour, seems hardly sufficient to warrant the increased weight. It therefore seems probable that immediately the really critical situation as regards steel and skilled labour is passed, large vessels will no longer be constructed of concrete.

Ideal Points aimed at.—Designers and builders are striving to produce a reinforced concrete vessel: (*a*) That will as nearly as possible reduce the weight of the hull to that of a steel ship of the same deadweight capacity; (*b*) that will contain not more than one-quarter or one-fifth of the steel that is required in a steel ship; (*c*) that will be sufficiently strong and safe with a thin concrete hull to stand stresses and ordinary knocks and at the same time have the necessary density to ensure watertightness; (*d*) with a concrete that will not fracture by expansion and contraction, and that can be protected from disintegration in contact with acids, &c.; (*e*) that can be launched quickly after completion, without danger to the concrete work; (*f*) that after bottom and side damage has been repaired, can be put to work again quickly without waiting several weeks for the repair work to set and harden.

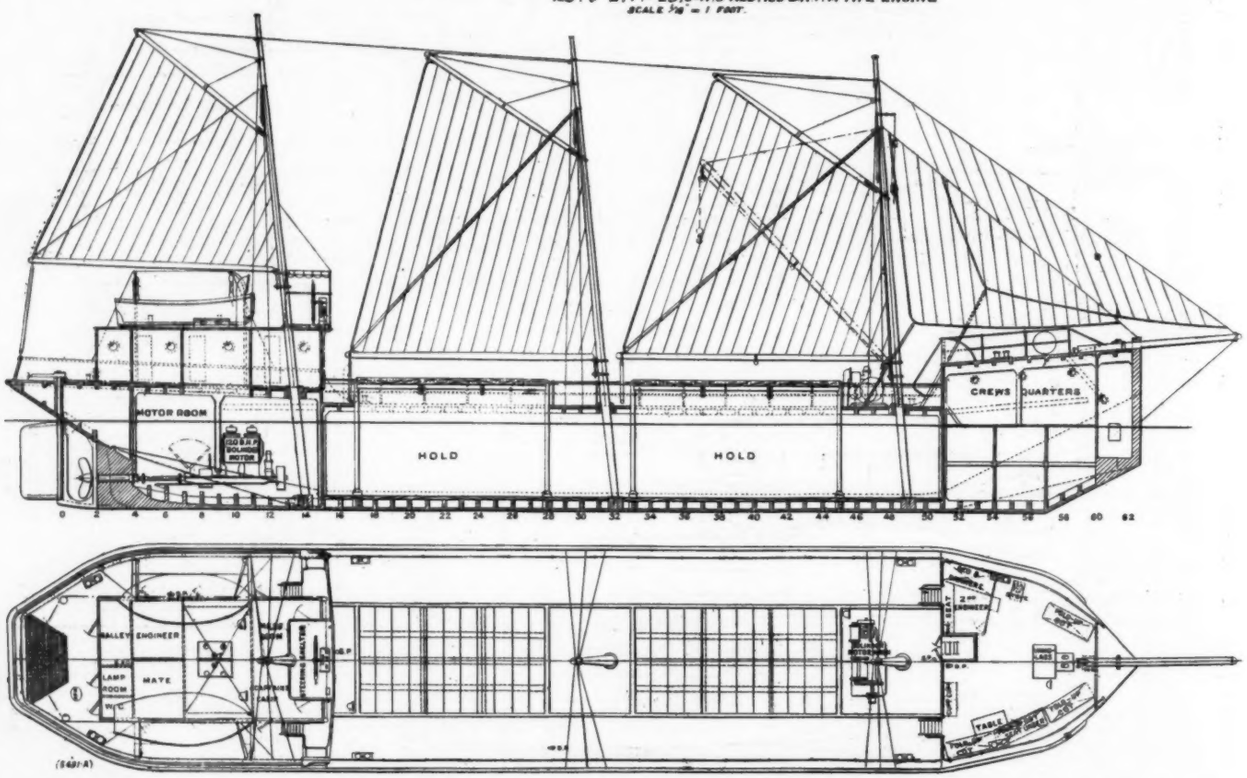
Co-operation of Experts.—It is necessary to combine the knowledge and experience of the designers of reinforced concrete work on land with that of a naval architect who has had experience in the design and construction of vessels of the type to be adopted. Neither party can at present hope to attain the best results without the other. A reinforced concrete vessel can be of similar design generally to that of existing steel or wooden ships, although many modifications and improvements can be more easily applied to the former.

Consideration of Design.—The underlying principles are to use only the amount of steel necessary to take up the tensile stresses and for the concrete to do the rest and stiffen the structure. The "web" of the transverse section of a steel ship—that is, the connection of the deck and bottom plating—requires a considerable weight of steel plates which in the reinforced concrete vessels is mostly substituted by concrete. From the naval architect's point of view, there are no great difficulties in the design and construction of these vessels. River vessels have to provide only for ordinary hydrostatic pressures, except where they have to ground on an uneven bottom, and the shocks and stresses due to coming in contact with other vessels, quay walls, &c. Seagoing vessels have to provide for dynamic forces due to mooring, berthing, docking, &c., as well as sagging, hogging, and torsional strains when striking or falling in a heavy sea. The vibration of a ship in ballast after striking a wave may be found one of the most serious problems in concrete ships. The bending and hogging strains due to wave conditions can be readily calculated, but the torsional and racking strains cannot. Shallow-draught and river vessels, having as a rule only the strains due to unequal loading, grounding, &c., thus allow the scantlings to be lighter than is necessary for seagoing vessels.

The ideal design would appear to be a vessel with longitudinal construction (dispensing with two-thirds of the usual floors and frames), fitting only a few web-frames and as many bulkheads as possible, and in addition to the usual longitudinal rods, a series of diagonal ones. In larger size vessels it would no doubt be advisable to fit a centre bulkhead for the full length of the ship, but in any case it is advisable for cargo vessels to have the hatch coamings continuous all fore and aft, as shown in Fig. 1. In smaller vessels a continuous carling, even if it projects 6 in. above the deck, is desirable. The calculations are in general similar to those of a steel ship. A set of curves of bending moments and shearing forces for a 300-ton deadweight vessel are given on Figs. 4 and 5, page 368.

It is not difficult to design a reinforced concrete vessel with graceful form, nice curved lines and a handsome sheer, though difficulty and expense are involved in building and in keeping the steel reinforcement in place during moulding and casting. To overcome these difficulties, the author designed the "straight-lined" vessels in July, 1917, and published a number of designs wherein all the transverse sections are straight lines throughout the ship, the sheer being also in straight lines. The central portion of the ship for more than two-thirds of the length is rectangular except for the angle of the bilge which forms a double chine (see Figs.

Fig. 1. GENERAL ARRANGEMENT. REINFORCED CONCRETE COASTER
125'0" B.P. × 25.0" × 11.9" MLD. 120 B.H.P. M TYPE ENGINE
SCALE 1/16 = 1 FOOT.



* Paper read at the Spring meetings of the fifty-ninth session of the Institution of Naval Architects, March 22, 1918.

3 and 7). If the steel reinforcement is not kept in its proper position both vertically and horizontally in the thin slab walls of the shell, bulkheads, hatch coamings, bulwarks, casings, &c., a considerable amount of the strength of the reinforced concrete structure will be sacrificed. Take for an example a 3-in. slab curved vertically, horizontally and diagonally, as is the case on the bow of an ordinary ship-shaped vessel. It is almost impossible to keep all the steelwork in its proper position, and a deviation of only ¼ in. of the bars one side will bring them so close to the surface as probably to throw off the concrete, or if set inwards will considerably reduce the strength of the slab locally. Furthermore, if the steel rods be not true to line, they tend to straighten out when subject to a tensile pull and cause the concrete to burst off, besides reducing their effectiveness by introducing secondary stresses.

The unit method of construction is being tried, but the advantages for ship work have yet to be proved, while the disadvantages are serious; so that the monolithic system, which makes it easy to obtain continuity of strength, is almost universally used. For small vessels, barges, &c., a slab form of construction (Fig. 10, page 369) should be more economical, as it dispenses entirely with floors and frames, side keelsons, stringers, beams, &c. The shuttering, being reduced to a minimum, is quickly placed in position and more rapid construction attained. Bulwarks and hatch coamings are difficult to design for avoiding damage whilst loading or discharging cargo. The former can therefore be dispensed with and hinged stanchions and lifelines substituted, especially if the hatch coaming is made continuous. The latter should have a strong top and rest bar to avoid damage (see Fig. 9).

Fenders are necessary for all concrete vessels to protect the concrete, but in the experimental barge of 130 tons deadweight capacity referred to later, fenders have been entirely dispensed with on the advice of the concrete designer, the corners of the gunwale being well rounded and finished off with a mortar of one of cement to one of sand, so as to avoid being chipped when coming in contact with or striking other barges. A solid half-round for the gunwale, as shown on Fig. 10, and other chafing irons, are desirable, and may prove an advantage. It would be advisable to fit fenders to all vessels as a precautionary measure, at least for the present, following the usual method of fitting close against the concrete work instead of a few inches off the shell with wood chocks in way of the bolts. A fender at the bilge, as shown on Fig. 9, will protect the concrete, and at the same time act as a bilge keel. All edges or corners throughout the vessel should be rounded or bevelled where possible to prevent being chipped or broken off. If the concrete is subject to considerable rubbing or chafing it will wear away.

There are the following methods of reinforcement: (*a*) Wire netting, expanded metal, and similar meshwork with or without bars; (*b*) flat bars, special bars, steel joists, &c.; (*c*) round bars of varying diameters. All of these are suitable for either the unit method or the monolithic method of construction, and may be used either singly or in combination. The wire netting and expanded metal is not likely to be adopted for the shell work of seagoing vessels, because of the difficulty in keeping it true to line and obtaining homogeneity, as well as its excessive cost and the difficulty in varying the network sufficiently to suit the stresses. Various sections, other than round bars, have been adopted in a number of cases, especially in America, but no doubt the round bars will be generally adopted, because they utilise the steel without waste, are easy to arrange in position, easier to bend, more readily obtainable, and adapt themselves to a minimum quantity of concrete. Some claim that mechanical bond bars (to which kind all special bars belong) develop greater adhesion than round bars, but many reinforced concrete experts think the claim fallacious. The larger steel bars are arranged longitudinally, generally in way of the deck line and the bottom of the ship, while there are also rods of nearly the same size arranged transversely, the whole being connected by small bars from ⅛ in. to ¼ in., forming, say, a 6-in. mesh over the whole surface, making, as far as possible, a monolithic structure, a reduction in the number or total sectional area of the rods, both longitudinally and transversely, being arranged towards the ends of the vessel.

There are four methods of jointing the steel rods: (1) By a long overlap; (2) by a short overlap with hooked ends; (3) by welding; and (4) by turnbuckles or other mechanical attachment. The long overlap, which is usually 40 diameters of the rod, although some go as low as 20 diameters, relies entirely upon the adhesion or grip of the concrete to the bar. The short overlap of, say, 12 diameters in the small rods and 18 diameters in the rods over 1 in. diameter, relies mostly upon the hooked ends and appears to be a satisfactory solution, as it reduces weight without sacrificing strength. Welding is certainly the most economical as regards weight, but if done in the shop makes the rods difficult to handle and keep in shape, and if in place may result in a local weakening of the rod at the weld. A mechanical connection such as a turnbuckle, to unite screwed ends of the rods, is sometimes adopted for special purposes. The cost of welding and mechanical connection is usually considered prohibitive. In each of the above cases, the loss due to the weakness of all riveted seams or butts in a steel ship is avoided. In order to resist the diagonal tensile stresses induced in a beam by the action of the shearing force, stirrups are frequently introduced extending between the tension and compression members. They may be considered as the web members of a truss system, the triangulation of which will vary as they are placed vertically or diagonally.

While there is a well-defined theoretical method employed by designers of reinforced concrete structures for the determination of the sections, the calculations depend upon the use of coefficients determined from experiments which have all been made upon concrete under the conditions in which it is employed in buildings, and consequently the experimental data for shipbuilding work have yet to be derived. For this reason the paper leaves out consideration of the usual practice in allowable stresses which might, if included, lend colour to the supposition that calculations could be made quite definitely on present experience. For deriving the equations for determining the properties of reinforced concrete sections, it is necessary to know the moduli of elasticity for concrete and steel and the ratio as used in combination, because, while the modulus of steel is fairly constant up to the yield-point and is well known, the moduli of concrete vary with the quality of the concrete and the stress upon it, the modulus being greatly reduced as the stress increases. Therefore, in a reinforced concrete beam the ratio of the moduli of elasticity that is used for determining the position of the neutral axis and the other properties of a section is not the ratio that exists between the initial moduli of elasticity of the two materials. As the modulus of the concrete would vary to some extent with the constant or intermittent immersion in water, it is evident that the ordinary modular ratio of 1 to 15 that is used for structures may not be at all appropriate, having regard to the richer mixture of concrete employed and the greater factor of safety previously advocated.

The resistance of concrete to tension is generally neglected, and it seems desirable to neglect it in ship design, but attention should be given to the fact that concrete is comparatively weak in tension, and therefore may be rather unsound for some part of the full thickness of the section, and consequently the watertightness depends on a section of less thickness. It seems advisable at the present time to employ a factor of safety of 6 as regards the crushing strength derived from experiments on concrete blocks made in the ordinary way and allowed to dry out in the air, such crushing strength being that obtainable at three months.

In ordinary building work, considerable dependence is placed upon the "adhesion" of concrete to steel, as it is called, but perhaps it would be better to speak rather of the "grip," as indicating that the bond between the steel and the concrete is derived chiefly from the contraction of the concrete in hardening in air. Therefore precaution is taken to give a mechanical bond by hooking or bending the ends of all reinforcement. It will be found advantageous to employ concrete richer in cement than that ordinarily used for buildings, and made with ballast or other coarse material (sometimes called aggregate) restricted in size. There is also another element in question, as to what reduction in stress, if any, should be allowed in concrete which is always kept in water and that which is alternatively wet and dry, while it is necessary in addition to ascertain what effect salt water has on the strength of concrete as used in a vessel, although data go to show that salt water has no effect on a dense concrete; this is a subject that can well be experimented with in regard to concrete shipbuilding. In a steel ship, say, up to 1,000 tons, it is usual to allow a stress of 8 tons per square inch on the steel, but in view of the uncertainty of the behaviour of the concrete work at sea, it will no doubt be found advisable to allow only one-fifth of the ultimate tensile resistance for the reinforcement.

Weight of Hull.—The weight of reinforced concrete hulls is the most serious problem in the adoption of this type of vessel, the concrete being 143 lb. per cubic foot,

Fig. 2. PATENT STERN FRAME.

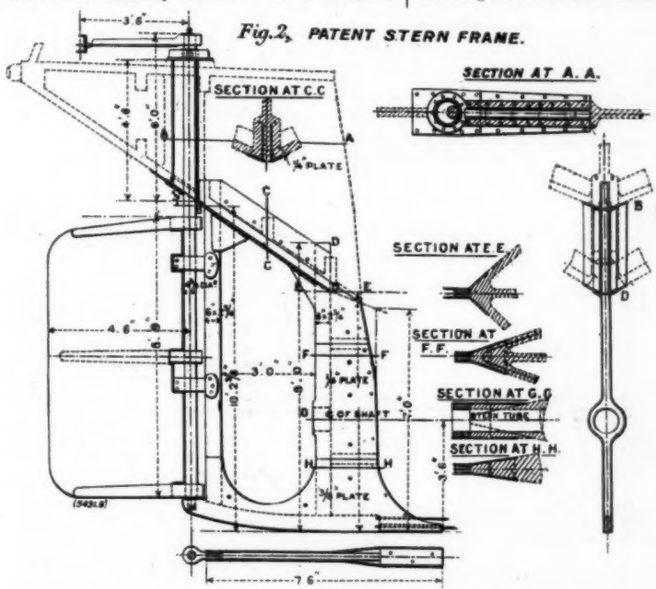
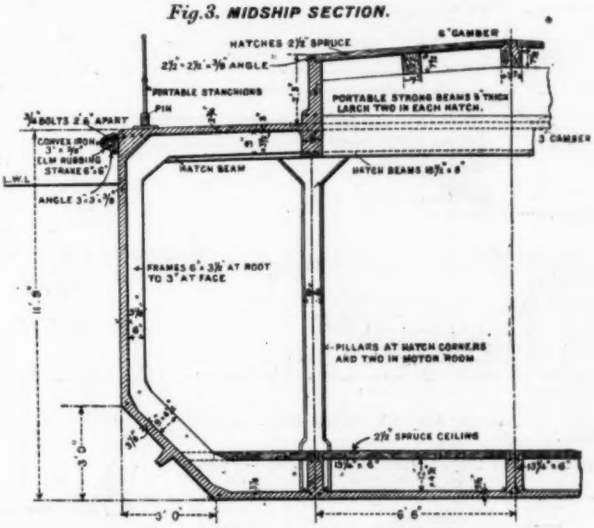


Fig. 3. MIDSHIP SECTION.



plus the reinforcement. The bare hull with fittings of a coasting vessel of, say, 300 tons deadweight will weigh 130 per cent. more than that of a steel vessel, while the increase in total displacement is about 40 per cent. (see table overleaf). Put in another way, if a concrete coaster were built of the dimensions and coefficient of fineness of a 420-ton deadweight steel vessel, it would only carry 300 tons deadweight on the same draught. The linear increase (length, breadth and depth) would be 12 per cent. to 14 per cent. greater for a concrete vessel than for a steel vessel. The table overleaf is a comparison of a 300-ton deadweight auxiliary coaster in concrete, wood and steel. The figures in the table of the 300-ton concrete vessels are based on the ordinary method of construction as shown by Fig. 1, and not the author's improved method of construction shown on Fig. 8. The practice of stating that a concrete hull is from 50 per cent. to 70 per cent. heavier than a steel vessel of the same dimensions does not give a fair comparison, because the concrete hull would carry much less cargo. The method of comparing the weights to vessels of similar deadweight has therefore been adopted. It will be seen that the total steel is only 27 per cent., the reinforcement alone accounting for 25 per cent. of that of a steel vessel of the same deadweight capacity. The weight of the bare hull of the 500-ton vessel, illustrated by Figs. 8 and 9, is only 400 tons, which shows a reduction of 15 per cent. as compared with the figures of the 300-ton concrete vessel. A 1,000-ton deadweight towing lighter would weigh about 90 per cent. to 100 per cent. more, the displacement being about 25 per cent. more, and the linear increase 7 per cent. more than that of a steel lighter of the same deadweight. The percentage difference in weight gradually increases up to, say, 2,500 tons deadweight.

Disadvantages.—The principal disadvantages are: (*a*) Greater weight and consequently greater displacement for the same deadweight; (*b*) increase of net tonnage and consequent increase in port and harbour dues; (*c*) increased cost of building and launching

REINFORCED-CONCRETE VESSELS.

REINFORCED CONCRETE COASTER.

Fig.4

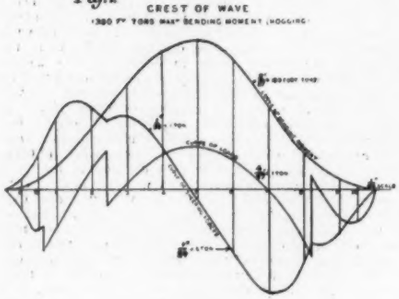


Fig.5.

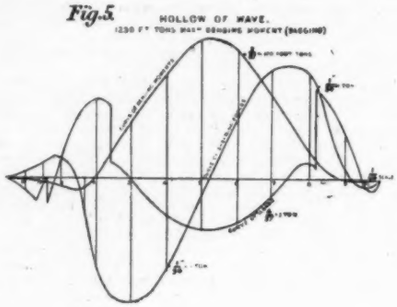


Fig.6.

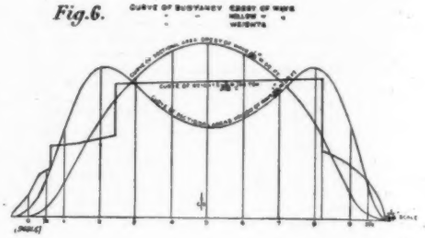
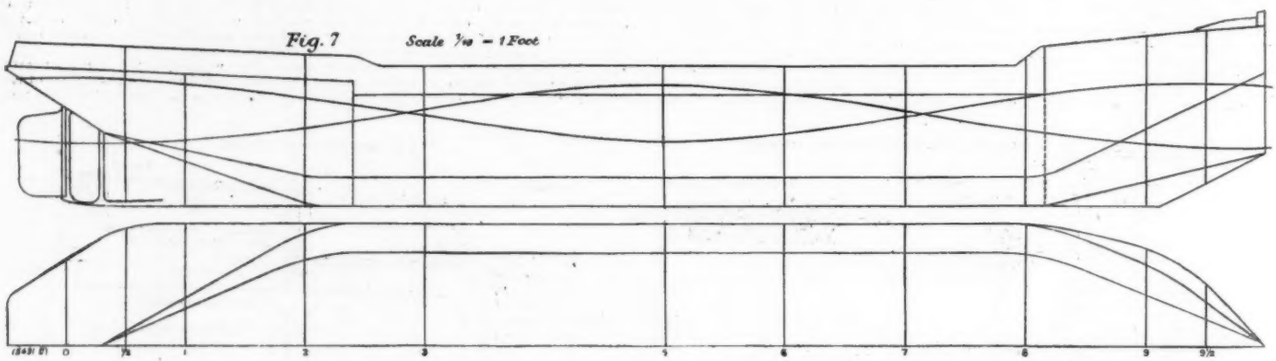


Fig. 7 *Scale 1/8 = 1 Foot*



ways; (*d*) longer time to repair if bottom repairs are necessary.

Advantages: (1) Much less steel than is necessary for a steel vessel, and no waste due to scrap; (2) no loss of strength due to rivet holes and joining as in a steel vessel; (3) cheaper and quicker construction; (4) very little skilled labour, no platers, anglesmiths, or riveters required; (5) longer life and reduced depreciation; (6) reduced upkeep and repair bill; (7) freedom from dry rot as in wooden vessels and freedom from corrosion as in steel vessels; (8) smoother surface and less skin friction.

Comparison of a 300-ton Deadweight Vessel in Concrete, Wood and Steel.

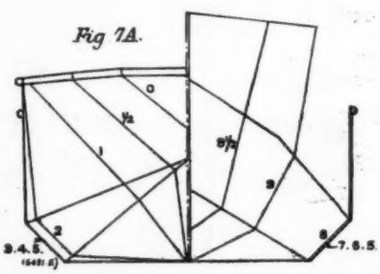
—	Reinforced Concrete.	Wood.	Steel.
Length	125 ft.	108 ft.	105 ft.
Breadth	25 ft.	23 ft. 9 in.	21 ft.
Depth	11 ft. 9 in.	10 ft. 7 in.	11 ft. 4 in.
Draught bottom of keel aft	10 ft. 3 in. (no keel)	10 ft. 3 in. (keel)	10 ft. 3 in. (no keel)
Deadweight cargo ..	300 tons	300 tons	300 tons
Cubic capacity of holds and hatchways	17,320 ft.³	12,350 ft.³	12,500 ft.³
Displacement ..	640 tons	495 tons	455 tons
Time to construct ..	4 months	8 months	6 months
Weight of steel ..	28½ tons	15 tons	110 tons
Weight of bare hull ..	290 tons	140 tons	120 tons

With regard to depreciation: So far as can be at present ascertained, the concrete should last for several hundred years. Depreciation, however, may take place in the steel bars due to corrosion and fatigue of the metal. The former will only occur if the concrete is permeable to water and air: this can be avoided by a careful selection of the materials used and by strict overseeing of the mixing and casting operations. The question of fatigue of the metal would depend upon the stresses set up on the steel due to the "working" of the ship, but this is not likely to affect the vessel up to, say, the first fifty years of its life.

Local Strength.—Damage as a result of a collision should not be so serious as some critics appear to imagine. As an instance of the strain reinforced concrete is capable of withstanding, there is in Flanders to-day the tank of a water tower that was brought to the ground with a crash by the legs having been shot away, and yet that tank is still capable of holding water. It is 66 ft. by 33 ft. by 8 ft. 6 in. deep. The forces set up by collision are practically incalculable, and depend on the speed of collision, the angle of impact, the point at which impact occurs, and other factors. However, the local strength of the structure can be arranged to withstand a momentum or blow which compares quite well with ordinary steel construction. The repairs can be made quickly, but bottom repairs may require three weeks to harden before the vessel can be loaded and put to sea.

(To be continued.)

Fig 7A.



SOCIETY OF GLASS TECHNOLOGY.

The fifteenth meeting of the society was held on Wednesday, March 20, in the rooms of the North of England Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne. In the absence of the president, Mr. S. N. Jenkinson presided over a large gathering of members.

Mr. S. N. Jenkinson read a paper on "*Some Causes of Pot Failure.*" The causes dealt with are honeycombing holing, external cracks, and excessive solubility of pot bottoms. Observations have been made on pots made of two kinds of clay heated both in direct-fired and gas furnaces.

The conclusions drawn were that as regards pitting a high temperature (as attained in the gas-fired furnace) was beneficial, and of two clays, the more aluminous was the better. External cracks were regarded as arising from sudden fluctuations of temperature, most frequent with a coal-fired furnace; whilst internal cracks developed as the result of too rapid absorption of heat by the batch. Honeycombing occurred as the result of careless picking of raw clay, nodules of pyrites being eaten out rapidly by the glass. Although the bottoms of the pots are cooler than any other part of the pot, it was found that they dissolve faster than any other part.

In conjunction with Mr. G. V. Wilson, B.Sc., who examined the pot fragments microscopically, the conclusion was drawn that the presence of sillimanite formed in the pot at a high temperature, acted as a protective agent.

Mr. A. P. Roxburgh read a paper entitled "*A Note on a Coke Gas Producer Fired Tank Furnace for the Production of White Glass.*" The author dealt with the need of fuel economy in all industries requiring a high temperature. He described the preliminary experiments undertaken with Mr. Ferry, which had led to the evolution of the new tank furnace.

In the latter the producer was built as part of the furnace and was charged from a hopper above, the charge for the furnace already built being about 1 cwt. per hour. Special arrangements were made for cooling the fire bars and for rotating them so as to remove ash. The gas for the producer was taken off at a point below top of the fuel bed and passed through a dust chamber where dust was trapped and the gas was thereby cleaned. The secondary air was recuperated, although improvements in this respect were being worked out. An actual furnace was in operation for the melting of lead glass and the results obtained so far were encouraging enough to proceed with further experimental work.

A third paper was read by Mr. S. English, M.Sc., on "*A Simple Device for Preheating the Gas and Air in a Blowpipe.*" Mr. English mentioned other attempts made to effect the same purpose, and then explained his own device, which consisted in an electrically heated device arrangement. A very hot flame was produced, and it was possible to work Jena combustion tubing to blow a bulb on it after softening by means of the flame. Vigorous discussion followed the reading of the papers.

During the day visits were paid by members of the society to the works of Messrs. Lemington-on-Tyne Glass Company, Limited, George Davidson and Co., Limited, Gateshead and Tyneside Glass Company. Appreciative references and votes of thanks were passed to the directors of these works for their courtesy. The next meeting, on April 17, at the University, Sheffield, is the annual general meeting. The business will include: (1) Presentation of the annual report and balance sheet. (2) Election of Officers. (3) Amendment of rules. (4) Presidential address. (5) A paper by Mr. G. V. Wilson, B.Sc., "*On the Synthetic Production of Crystals of Glass Constituents.*"

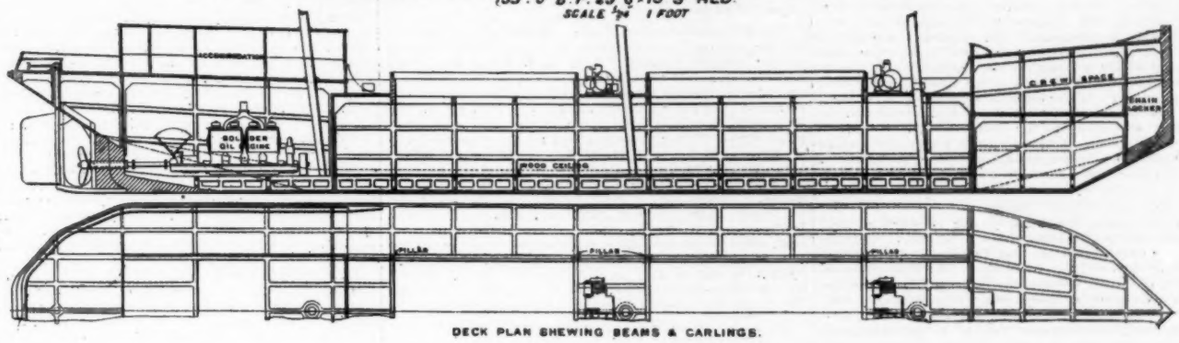
Ex-Officers' Employment Bureau.—An association is being formed at 8, Regent-street, S.W. 1, under the chairmanship of Lord St. Davids, and with Viscountess Falmouth as hon. treasurer, to assist officers to find civil employment when leaving the army, either before or after peace. Firms who are likely to have vacancies are asked to enroll themselves; they will receive particulars of officers seeking employment.

A 7,900-ton Concrete Ship.—News from an American Pacific Port states that the world's largest concrete ship has been launched and named "The Faith." The vessel is 320 ft. long and has a displacement of 7,900 tons. It will have a speed of 10 or 11 knots. The advantages claimed for this type of vessel are:—1. The use of concrete in no way interferes with the construction of steel ships. 2. Concrete vessels can be built at the present cost of wooden vessels. 3. Concrete vessels of 7,900 tons can be launched within 90 days. The builder of the vessel has stated "When this boat has passed her tests, I expect we shall send her to the Orient and when she returns we shall know all about her qualities. At present there are no insurance quotations covering concrete ships. The matters relating to these vessels are as new to everyone else as they are to ourselves."

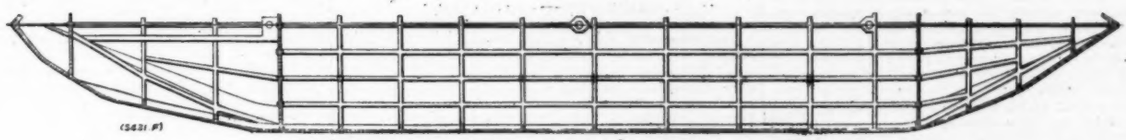
REINFORCED-CONCRETE VESSELS.

(*For Description, see Page* 366.)

Fig. 8. GENERAL ARRANGEMENT PLANS OF 500 TONS REINFORCED CONCRETE COASTER
(55'. 0" B.P. 29' 6" 13' 3" MED.
SCALE 1/24 1 FOOT



DECK PLAN SHEWING BEAMS & CARLINGS.



BOTTOM PLAN SHEWING FLOORS & KEELSONS WITH CEILING REMOVED.

Fig. 9. MIDSHIP SECTION OF 500 TON COASTER.

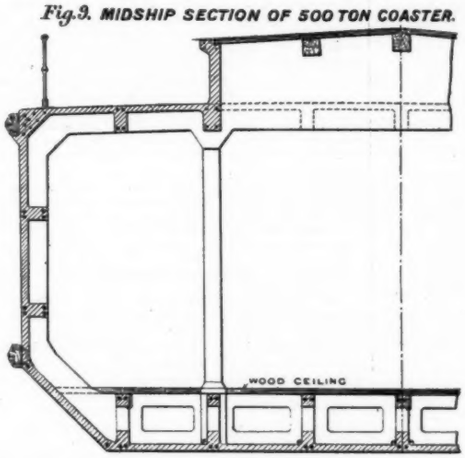
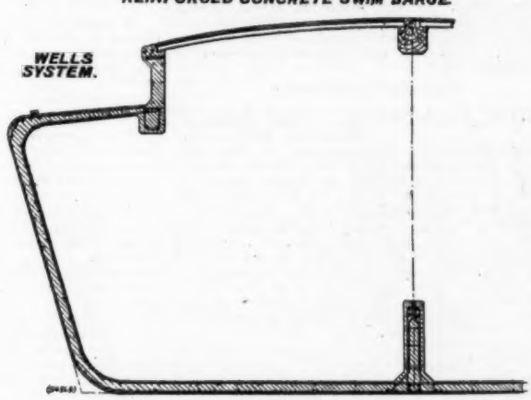


Fig. 10. MIDSHIP SECTION REINFORCED CONCRETE SWIM BARGE.



CONTROL OF MOTOR TRANSPORT.—On the invitation of the President of the Board of Trade, the Commercial Motor Users' Association has nominated Mr. Walter Wolsey, Junr. (managing director of Messrs. Thomas Tilling, Limited), and Mr. Frederick G. Bristow, F.C.I.S. (secretary of the Commercial Motor Users' Association), to serve on the panel of eight motor transport experts who are to act as a Central Advisory Committee to the newly-formed Road Transport Board. We have given in former issues a large amount of data pointing to the activity of the Commercial Motor Users' Association.

ASSOCIATION OF ENGINEERING AND SHIPBUILDING DRAUGHTSMEN. MERSEYSIDE BRANCH.—In connection with the Merseyside branch of the Association of Engineering and Shipbuilding Draughtsmen, an interesting lecture on "Strength Considerations in Ships" was delivered by Mr. E. Sutton, B.Sc., A.M.I.N.A., on March 26, at the Liverpool University. Mr. L. Backhouse presided. The lecturer first dealt generally with the nature of the forces acting on a vessel at sea, and the conditions which a vessel must satisfy to be successful structurally. In view of the indeterminate nature of many of the forces acting, and the complexity of the stresses set up, he showed that the mass of data which had been accumulated as the result of actual experience at sea must form the basis of all strength consideration. It was the function of scientific investigation and research, to analyse and correlate such data in order to arrive at correct principles and criteria which serve to guide the naval architect in ensuring a satisfactory result, combined with economical use of materials. The lecturer then dealt in some detail with the principal methods of calculation so far evolved as regards longitudinal and transverse strength, showing the assumption on which they are based, the reasons for accepting the results as a satisfactory means of comparison, and the limitations of these. The question of statutory freeboard so far as affected by strength according to present rules, and the work of the recent Load Line Committee, were touched upon. The lecturer concluded with notes on structural arrangement and general tendencies in structural design.

PERSONAL.—The Government having requisitioned their offices in Savoy-court, the Metropolitan Water Board have removed to their new Central Offices, Southplace, Finsbury Pavement, London, E.C. 2. The Board's telegraphic address will be "Water Board, Ave, London," and the telephone numbers, London Wall, 6687–91.—We are informed that Schaffer and Budenberg, Limited, has now become entirely a British undertaking, and that the name of the company has been changed to "Budenberg Gauge Company, Limited." Mr. C. F. Budenberg, M.Sc., a natural born British subject, who has been the manager of the business for the past twenty-nine years and managing director since the company was incorporated in 1902, has purchased all the issued shares, and these are now held by the trustee of a deed of settlement made by Mr. Budenberg for the benefit of himself and his family. Mr. Budenberg will continue to act as managing director, and there will be associated with him as directors, Mr. R. M. Chiswell, B.A., and Mr. R. H. Jackson, A.M.I.Mech.E., both of whom have been connected with the business for many years.—Mr. C. L. Faulkner, formerly of Suffolk House, Laurence Pountney Hill, E.C. 4, informs us that from the 2nd inst. he has entered into partnership with Messrs. Bolling and Lowe, 2, Laurence Pountney-hill, E.C. 4.

THE BRITISH ELECTRICAL AND ALLIED MANUFACTURERS' ASSOCIATION.—The annual general meeting took place at the offices of the association on the 28th ult., when the report and income and expenditure account and balance sheet for the financial year ended September 30, 1917, were adopted; and the following members declared on ballot to have been elected to fill the five vacancies on the council: British Electric Transformer Company, Limited; Browett, Lindley and Co., Limited; Mather and Platt, Limited; C. A. Parsons and Co., Limited; and Yates and Thom, Limited. The chairman referred to the appearance of the association's representatives as witnesses before the committee appointed by the Board of Trade "to consider the question of the electrical trades after the war." The report of that committee had not yet been published; but he did not think he would be committing any breach of confidence in stating that he believed the report was a very strong one, and that it would be received with gratification by this industry, particularly as it was understood to speak largely along the lines of the association's evidence. Turning to the latter's work during the past session, two important reports in which the industry was interested had made their appearance. The first was that of Lord Buckmaster's Committee on Pre-War Contracts (Cd. 8975) which, he regretted to say, appeared to afford little direct practical help to contractors but, in traversing old ground, offered some new suggestions of which, failing Government action, they might be able to avail themselves. The second was the Coal Conservation Sub-Committee's Report (Cd. 8880). This deserved their very careful attention, and would, he hoped, shortly be the subject of action by the association. As to association's conditions of contract, it was satisfactory to record that less difficulty in settling contracts was experienced and their conditions were making steady headway. The subjects of research and education were in the association's front line of action. Standardisation had made satisfactory progress during the year. As to other matters, they were in close touch with the work of the Federation of British Industries and the British Empire Producers' Organisation, and they were working jointly in many matters with other associations and institutes. The articles of association had been entirely recast; this was now an association for manufacturers exclusively.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The urgent necessity of our troops on the Western Front for a constant and increasing supply of munitions and other war material is creating a still further impetus in the steel trade, and a very special effort is being put forth in the West of Scotland to cope with this serious demand. Mills continue to run to their fullest possible extent, and it is certain that nothing will be left undone which may in any way speed up the production of the requisite amount of steel of all grades. When the new mills—the construction of which is being rapidly pushed forward—are ready, steelmakers will have some chance of dealing with the arrears. In the shipbuilding yards it is also a case of ceaseless activity which means, of course, an exceptional strain upon the steel works, as plates, shapes and sectional material are in heavy demand to meet the wants of the Shipping Controller's programme. And all the time there must be a sufficiency of shell bar steel.

Malleable Iron Trade.—Material required for war purposes comprises the bulk of the production, and everything else must stand aside meantime. Government is the chief customer and Government's requirements mean the safety of the nation. It was expected that before this some scheme of "rationing" might have been devised whereby the ordinary mercantile consumers both at home and abroad might have benefited, but as yet no pronouncement on the subject has been made.

Scotch Pig-Iron Trade.—The demand for pig-iron of all grades, and notably for hematite, is keeping the smelters as busily employed as they have been at any period since the outbreak of war. More than ever now is the entire tonnage produced being reserved exclusively for those firms engaged on war work or on work of national importance.

Workers and the Spring Holiday.—The Glasgow Spring Holiday, which for some years now has been celebrated on Easter Monday, found the majority of those engaged on work of national importance at their posts, the critical situation on the Western Front having decided the workers to forego the much-needed holiday with its opportunities for rest, so that there might be no falling-off in the production of munitions or any other of the required material. In some instances, indeed, arrangements have been made to work extra shifts wherever and whenever this may be necessary, if by so doing the output can be in any way increased to meet the severe demand.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Holiday Abandoned.—The demands of the army, created by the developments of the German offensive, upset the plans for a holiday at Easter, which had been made at most of the works. In many cases, while the works had been looking forward with avidity to a well-earned break, a respite would have proved seasonable to overall and repair gear, &c., and only in departments such as those engaged on certain shells and gun parts, where the exigencies of the situation in France rendered work imperative, were the holiday arrangements cancelled. The sacrifice entailed on many thousands of workers who had to forego the prospective rest, was cheerfully borne, and, in the words of the message of appreciation sent to them from the Ministry of Munitions, they thereby earned the gratitude of the armies in France.

Rationing Scheme.—A scheme of considerable importance to the cutlery trade, for the inauguration of which the Cutlery Manufacturers' Association is practically responsible, has been launched, whereby it is hoped to secure for the trade an adequate supply of steel, iron and non-ferrous metals. The system on which the scheme is based will at once ensure the equitable distribution of the different metals which it comprehends, and it promises to guarantee regular supplies and the smallest amount of trouble to the manufacturers, besides simplifying the work of the Ministry of Munitions, by arranging for the allotment to the trade of a given weight of the requisite metals. The plan of the scheme may have appeared somewhat too exacting to the more conservative minded in the trade, but the strictest privacy with which the necessary confidential data supplied is to be treated, should outweigh even the most serious objections. The idea gives to the masters a unique opportunity of acting jointly for the common benefit of the trade as a whole, as well as that of their own individual concerns, and to their credit be it said, they are entering into the scheme with broadmindedness and great enthusiasm.

Iron and Steel.—More than at any time since the Government placed the embargo on the export of steel material, does it now seem desirable to have the restrictions on overseas trade slackened, if not altogether removed, because there is at present quite a marked margin between the volume of goods being produced and the extent of the home demand. Steelmakers in a number of cases are asking for orders, and in many of the smaller engineering concerns there is a desire to obtain work to keep in operation plant which has been freed by the fulfilment of Government contracts. The position on the Continent is sure to be reflected in the steel trade, more particularly because of the necessity for guns than by an increasing of the output for shells, there having been recently a pronounced drop in the call made on the latter department. But even after one has taken into account the possible demands of a purely military character, there should be a considerable balance of steel available for general commercial purposes. The acceleration in shipbuilding is being accompanied by an increasing demand for engineers' small tools, and there is a prospect of a heavy proportion of high-speed material being consumed in the satisfaction of orders of this character. An insistent demand is being made for scrap to take the place of pig-iron. Merchants are being asked to remove the whole of their scrap to iron and steel works, iron founders also being open to receive plenty of such metal.

South Yorkshire Coal Trade.—Work was stopped at all the pits for Easter. There is no appreciable change in the general outlook. Last week there was a big demand at munition works for cobbles, nuts and slack to cover the period for which a holiday had been at first arranged, but subsequently cancelled. Best steam coal is eagerly taken up by home consumers, and equal shipments are being made to allied countries, particularly to France and Italy. The house coal section shows very little variation. Merchants generally complain of shortage. Maximum prices obtain at the pit as follow. Quotations:—Best branch handpicked, 23*s.* to 24*s.*; Barnsley best Silkstone, 23*s.* to 23*s.* 6*d.*; Derbyshire best brights, 21*s.* to 22*s.*; Derbyshire house coal, 18*s.* 6*d.* to 19*s.* 6*d.*; best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.*; small nuts, 17*s.* 6*d.* to 18*s.* 6*d.*; Yorkshire hards, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire hards, 17*s.* 9*d.* to 18*s.* 9*d.*; best slacks, 14*s.* to 14*s.* 6*d.*; seconds, 13*s.* to 13*s.* 6*d.*; smalls, 9*s.* to 10*s.*, per ton at the pit.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Owing to inadequate railway facilities for delivery of Cleveland pig-iron to home consumers under the March allocations, cancellation of contracts has had to be on an extensive scale, and makers' stocks have accumulated considerably. Foreign business is quiet, but the assumption of the control by the Italian Government of all shipping to Italian ports will, it is expected, lead to heavier despatches to that country. For home consumption, No. 3 Cleveland pig, No. 4 foundry, and No. 4 forge all stand at 95*s.*, and No. 1 is 99*s.*; and for shipment to France and Italy, No. 3 and the lower qualities are quoted 114*s.*, and No. 1 is 119*s.*

Hematite Iron.—Licences for shipment of East Coast hematite iron are being more liberally issued, and this may be taken as an indication that output, supplemented by the larger production of basic iron, is more than sufficient to meet all home requirements. Nos. 1, 2 and 3 are 122*s.* 6*d.* for home use and 147*s.* 6*d.* for export to France and Italy.

Manufactured Iron and Steel.—Producers in these industries have little or no material to offer in the ordinary way of commerce, Government needs and requirements of the shipyards taking up practically all the make. Output of shipbuilding requirements is particularly heavy, so that the huge demands are well met, but expansion of the shipbuilding programme will make greater calls on the steel plant. These, it is believed, will be satisfactorily dealt with. To home customers common iron bars are 13*l.* 17*s.* 6*d.*; best bars, 14*l.* 5*s.*; best best bars, 14*l.* 12*s.* 6*d.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 17*s.* 6*d.*; packing iron and steel (parallel), 13*l.* 10*s.*; packing iron and steel (tapered), 15*l.* 15*s.*; steel bars (no test), 15*l.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel joists, 11*l.* 2*s.* 6*d.*; steel hoops, 17*l.* 10*s.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.*—all f.o.t. at makers' works. Prices for export are not fixed, but they may be given approximately as from 2*l.* to 3*l.* above home quotations.

Shipments of Iron and Steel.—Shipments of iron and steel from the port of Middlesbrough during March were the smallest recorded since the outbreak of war, aggregating only 35,574 tons—a decline as compared with February of 1,944 tons, and a drop as compared with January of 16,144 tons. Of the 25,950 tons of pig-iron cleared last month, 22,200 tons went abroad and 3,750 tons coastwise. This compares with 22,993 tons sent abroad and 3,498 tons coastwise in February, the total decrease being 541 tons. Manufactured iron and steel despatched amounted to 9,624 tons, of which 8,579 tons went to foreign ports, and 1,045 tons coastwise, as compared with total February clearances of 11,027 tons, of which 10,427 tons went abroad and 600 tons coastwise.

Coke.—Home demand for coke is heavy and considerable business is passing. Supply is very ample. Average blast-furnace kind is 33*s.* at the ovens, low phosphorus quality 35*s.* 6*d.* at the ovens, and foundry description 38*s.* for home use.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—There is really hardly anything to report this week owing to the interruption of the holidays. Operations will not be resumed at the collieries until to-morrow, the miners having been given a holiday during the first three days of the week. The result is that though the Exchange was formally open yesterday and to-day until noon, very few people put in an appearance, and practically no fresh business was transacted. In a sense the holidays have been welcomed; an opportunity has been afforded for clearing some of the stocks which were accumulating, but there is still a glut of small coal which it does not seem possible to get rid of altogether. Gas-producing coals, however, are in demand, and stocks have been depleted.

Newport.—No business has been done this week in Newport coals consequent upon the holidays. There is inquiry, however, for coals for inland consumption, and the indications are that Monmouthshire pits will be kept going fairly well at least during the latter part of this week and the beginning of the next.

South Wales Colliery Examiners.—An agreement has now been signed on behalf of the South Wales Coalowners and the Monmouthshire and South Wales Colliery Examiners' Association, and this, it is hoped, makes the end of a prolonged dispute with the coalfield. Under the new agreement a Joint Board is set up for dealing with questions affecting the terms of employment of colliery examiners. The Board will consist of 10 representatives from each side and a chairman on each side. The parties pledge their respective constituents to endeavour to avoid difficulties or disputes; but if difficulties do arise, the owners or the management, together with the officials, shall endeavour to settle all matters at the collieries, and, in the event of failure to settle the matters in dispute will be referred to the Joint Board, whose decisions may be retrospective in their application. No notice to terminate contracts is to be given by either side until the Joint Board has failed to agree. The new agreement is terminable by three months' notice, and collective notices to terminate contracts shall not be given during the continuance of the agreement. At a meeting of the Executive Committee of the Examiners' Association held on Monday, following the signing of the new agreement, it was decided to ask for an early meeting of the new Joint Board in order to discuss and decide upon a general wage rate and conditions of employment.

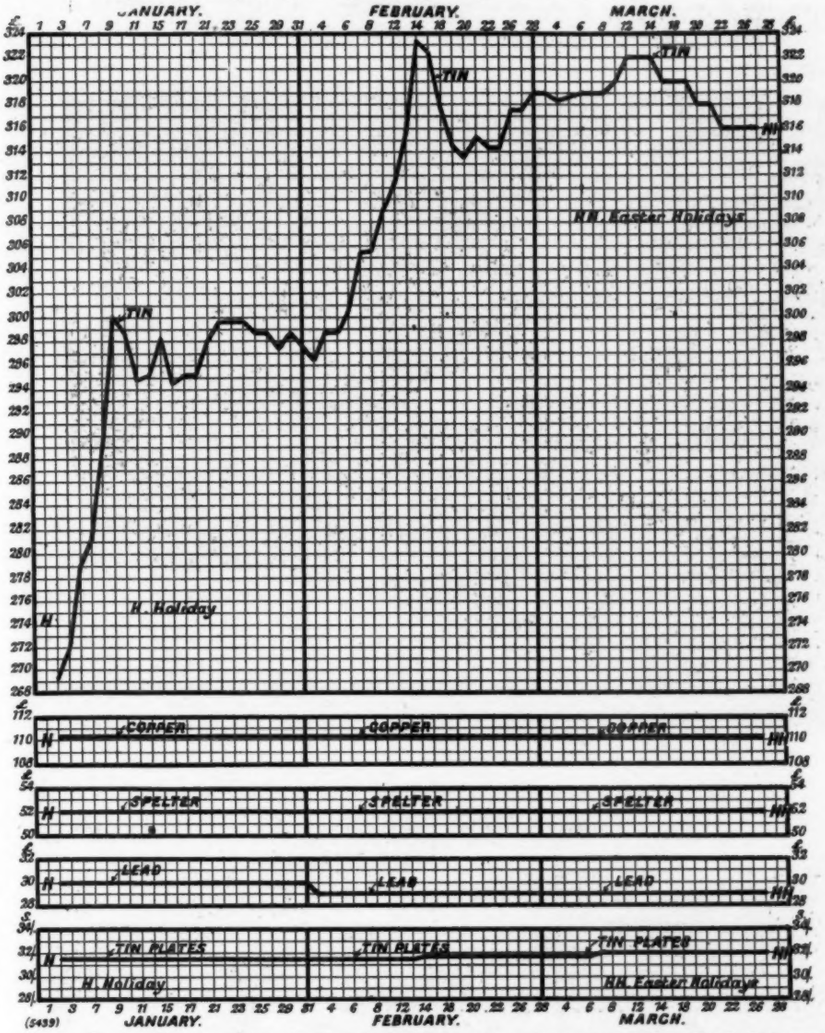
Miners' Unofficial Conference.—A disturbing element has again manifested itself in the South Wales coalfield. A conference of miners' delegates convened by what is termed the South Wales Federation Unofficial Reform Committee was held at Cardiff yesterday. Notwithstanding a public announcement by the Right Hon. T. Richards, M.P. (general secretary of the South Wales Miners' Federation) warning the miners of the coalfield of the mischievous character of the conference, upwards of 200 people from all parts of the coalfield were in attendance. Of these over 100 were said to be delegates directly representing miners' lodges of an aggregate membership of not far short of 100,000. Though probably this is an exaggerated claim, the movement has assumed such proportions as to cause disquietude. The chief aim of the conference was to agree upon a line of policy which would have the effect of putting obstacles in the way of the authorities in securing men for the army. Many of the speeches delivered were of such a character that they were not published, and the decisions arrived at were not such as would be commended by a loyal body of men. It is anticipated that definite action will be taken to counteract the movement, otherwise the results may not be altogether pleasant, as a comparatively few men are capable of a great deal of mischief-making if allowed to go on without let or hindrance on the part of the recognised trade union or of the authorities.

NEW GERMAN SHIPYARDS.—Under the style of the Hamburg-Elbe Yard, a shipbuilding concern has been formed in Hamburg with a capital of 4,500,000 marks. The new company will principally undertake the building of boats of uniform types, up to 5,000 tons, and will take over the engineering and shipbuilding business of F. H. Schmidt, at Wilhelmsburg near Hamburg, which had confined itself to building small vessels. The transformation of the Schmidt concern into a large, modern yard has already commenced. A Dusseldorf banking firm is interested in the new venture. In Lübeck a new shipbuilding company has been formed under the style of the Triton yard, the capital in the first instance being 1,000,000 marks. From the State of Lübeck a tract of land, on the Upper Trave, has been secured, a part of which is to be set apart for workmen's residences, &c. It is proposed to erect five slips, on which steamers of 10,000 tons to 15,000 tons will be built in series. The Reiherstieg shipyard in Hamburg recently received an order for 10 fishing steamers from a Hamburg firm, and this order has now been doubled; to save time and cost the 20 steamers will be built exactly alike.

"THE GUIDE TO SOUTH AND EAST AFRICA."—The 1918 (twenty-fourth) edition of this guide has now appeared. It is edited by Messrs. A. J. Brown and G. G. Brown, and is published by the Union-Castle Mail Steamship Company, Limited, 3 and 4, Fenchurch-street, E.C., at the price of 1*s.* net, or 1*s.* 5*d.* post free, throughout the United Kingdom. It is destined for tourists, sportsmen, invalids and settlers, who will find in its pages every item of information they require. The guide has been entirely rearranged, and the various subjects dealt with have been placed in a carefully-considered sequence, to simplify matters for the ordinary reader and facilitate reference by those using the book as a Gazetteer or for any other purpose. In making these alterations the requirements of a number of young men, now fighting in our armies, who may be expected to choose a life in the Colonies after the termination of the war, have been carefully borne in mind. In connection with the re-arrangement, the index has been altered and recast. The sections about South-West Africa (formerly German South-West Africa), about Portuguese Angolaland and about Katanga (Belgian Congo) have been re-written and enlarged, and give all available information, attention being directed to the extraordinary development by means of which the copper mines of Katanga are opening up a portion of the continent hitherto almost unknown. The Guide contains a series of excellent maps.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially Compiled from Official Reports of London Metal Markets.)



NOTE.—In the diagram above the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange, as far as they have been reported, for "fine foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. The prices are per ton. The price of tin-plates is per box of I.C. cokes free on board at Welsh ports. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each. On July 7, 1916, the Minister of Munitions issued a list of maximum prices and regulations governing the dealing in certain metals, &c.; thus the price of hematite pig iron was fixed at 6*l.* 2*s.* 6*d.*, Scotch at 5*l.* 14*s.*, and Cleveland at 4*l.* 11*s.* 6*d.* per ton.. Ship-plates were priced at 11*l.* 10*s.*, and heavy steel rails at 10*l.* 17*s.* 6*d.* per ton. These quotations are still in force. (For official regulations see page 45, vol. cii.)

CONGRES GENERAL DU GENIE CIVIL.—In the week from March 16 to 23, the "Congrès Général du Génie, Civil for the Study of After-War Programmes" held its first meeting in Paris. The Congress has been initiated by the Société des Ingénieurs Civils de France mainly to deliberate on the organisation of all industrial work in scientific, technical and commercial respects. Ten sections with about 30 subdivisions have been established for this purpose in various parts of the country, and the Congress discussed their recommendations. The section on public works and civil engineering dealt with water power, the rebuilding of places destroyed by the war, and also with the Channel Tunnel; the utilisation of tidal power and of internal-combustion engines for ship propulsion and of electric power for railways came before the sections on transports and on electricity. Technical instruction occupied the section on the national organisation of industrial work and the question of international adoption was also discussed by the section on mechanics, motors and machine tools in the first instance.

ASSOCIATION OF BRITISH ELECTRICAL ENGINEERS: ELECTRICITY SUPPLY SECTION.—A preliminary committee has been considering the desirability of forming an Association of British Electrical Engineers, Electricity Supply Section. The members of the committee are acting in their personal capacities and quite unofficially, but are doing so with the full approval of the councils of the associations which they represent. After drafting preliminary objects and articles of association, the committee interviewed the president of the Institution of Electrical Engineers, who has given the project his hearty support. The primary object of this section of the association is to safeguard the interests of all professional and technical men engaged in the electricity supply industry, but it is hoped that similar sections may be formed for those engaged in other branches of the electrical industries of Great Britain, each with its own council, which will be represented on a Grand Council to focus the activities of all engineers engaged in the electrical industries of the United Kingdom. The association will be in no sense a trade union, but will be constructed rather on the lines of the existing professional associations such as, for instance, the British Medical Association. The proposal to form this new association was recently discussed by the council of the Institution of Electrical Engineers, who have appointed a special Vice-Presidents' Committee to meet the members of the Preliminary Committee, and have agreed to call together mass meetings of professional and technical men engaged in the business of electricity supply throughout the country. Such meetings to be called both in London and at the local sections. At these meetings the project will be fully discussed and a permanent executive will be appointed, charged with the duty of giving effect to the proposed formation of the association.

NOTICES OF MEETINGS.

THE MINING INSTITUTE OF SCOTLAND.—Saturday, April 6, at 3 p.m., in the Royal Technical College, George-street, Glasgow. After the Annual Report of the Council and the election of office-bearers, Mr. David M. Mowat's paper on 'Capital Charges Contrasted along with Current Expenses" will be discussed; Mr. Henry Rowan's paper on "Stripping and Re-lining a Shaft at Cowdenbeath, Fife," will be discussed; Mr. Robert W. Dron's paper on "The Occurrence of Coking Coal in Scotland," will be discussed; a paper will be read by Mr. William Jarvie on the "Education (Scotland) Bill."

ROYAL SOCIETY OF ARTS.—Monday, April 8, at 4.30 p.m. Cantor Lecture: "Military Explosives of To-day," by James Young, O.B.E., A.R.C.S., F.C.S., Chief Instructor in Science, Royal Military Academy, Woolwich. Wednesday afternoon, April 10, at 4.30 p.m.: W. Lawrence Balls, Sc.D., Manager of Cotton Investigations for the Fine Cotton Spinners' and Doublers' Association, "Examples of Applied Science in the Cotton Industry." Professor William Bateson, D.Sc., F.R.S., will preside.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, April 9, at 5.30 p.m. Paper to be submitted for discussion: "The Derwent Valley Waterworks," by Edward Sandeman, M.Sc., M.Inst.C.E.

THE INSTITUTION OF RAILWAY SIGNAL ENGINEERS.—Tuesday, April 9, at 2.30 p.m., at the Midland Grand Hotel (Room 38), St. Pancras. After the presentation of past year's Report and Statement of Accounts, Mr. Thorrowgood will read a paper on "The Maximum Regulating Resistance and Maximum Shunt Resistance of Track Circuits."

THE RÖNTGEN SOCIETY.—Tuesday, April 9, at 8 p.m., at Burlington House, W., the Silvanus Thompson Memorial Lecture will be delivered by Sir Ernest Rutherford, F.R.S.

THE INSTITUTION OF ELECTRICAL ENGINEERS: SCOTTISH LOCAL SECTION.—Tuesday, April 9, at 7.30 p.m., at the Rooms, 207, Bath-street, Glasgow. Annual general and sixth ordinary meeting. The Annual Report for the closing session will be submitted. Paper: "The Control of Large Amounts of Power," by Mr. E. B. Wedmore, Member.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Wednesday, April 10, at 7.30 p.m., at the Royal Society of Arts, John-street, Adelphi, W.C., Captain Philpot will read a paper entitled "Some experiments with Notched Bars."

LIVERPOOL ENGINEERING SOCIETY.—Wednesday evening, April 10, at 8 p.m., at the Royal Institution, Colquitt-street, when a paper will be read by Mr. Reginald J. Fisher, Assoc.M.Inst.C.E., entitled "Bonus Payments to Labour as a Factor in Engineering Production."

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, April 11, at 7.30 p.m., a joint meeting of the Institution and the Electrical Section of the Royal Society of Medicine will be held at the Cancer Hospital, Fulham-road, S.W., when the following papers will be read:—Dr. E. P. Cumberbatch, "Diathermy: The Use of Electricity for Heating the Tissues of the Body in Disease"; Dr. R. Knox, "Single Flash (Instantaneous Radiography, its Possibilities and Limitations." (There will also be an exhibition of electro-medical apparatus.)

INSTITUTION OF MINING AND METALLURGY.—Thursday, April 11, at 5.30 p.m., at the Rooms of the Geological Society, Burlington House, Piccadilly, W. The Presidential Address will be delivered by Mr. Hugh F. Marriott.

THE OPTICAL SOCIETY.—Thursday, April 11, at 8 p.m., at the Imperial College of Science, South Kensington. Paper on "The Balsam Problem," by Mr. James W. French, B.Sc., Member of Council.

ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, April 12, at 5.30 p.m., a discourse will be delivered by Professor E. C. C. Baly, F.R.S. The subject will be "Absorption and Phosphorescence." Afternoon lectures next week at 3 p.m.:—On Tuesday, April 9, Professor John Joly, F.R.S., on "Scientific Signalling and Safety at Sea" (Lecture I); on Wednesday, April 10, Professor John Joly, F.R.S., on "Scientific Signalling and Safety at Sea" (Lecture II); On Thursday, April 11, Lieut.-Colonel C. S. Myers, R.A.M.C., M.D., F.R.S., on "Experimental Psychology" (Lecture I); on Saturday, April 13, Professor E. H. Barton, D.Sc., F.R.S., on "Musical Instruments Scientifically Considered" (Lecture I).

PREPARATIONS FOR PEACE AT THE SKODA WORKS.—The *Die Zeit* quotes from an article in the *Pravo Lidu* on the measures taken in the Skoda Works in preparation for peace. A special department of engineers and commercial directors has been formed to work out a detailed plan for converting the works from an undertaking for the manufacture of war products into one for the manufacture of peace products. A great department is being set up for the manufacture of machinery, especially agricultural machinery, for export, with the object in the first place of securing the Balkan market. The Skoda factories have large stocks of machines which will be thrown on the Russian market. It is expected that a great impetus to shipping will be witnessed in the Dardanelles, and part of the works will be devoted to the building of motor boats for export to Turkey and Bulgaria. Ships (for the Adriatic), motors, and flying machines are also to be built. We gave an illustrated description of the Skoda Works in our vol. lxxxv, page 298.

TRIPLE-EXPANSION PUMPING ENGINES FOR THE LONDON COUNTY COUNCIL.

CONSTRUCTED BY MESSRS. FULLERTON, HODGART AND BARCLAY, LTD., PAISLEY, TO THE DESIGNS OF MR. H. M. ROUNTHWAITE.

(*For Description, see Page* 363.)

Fig. 8.

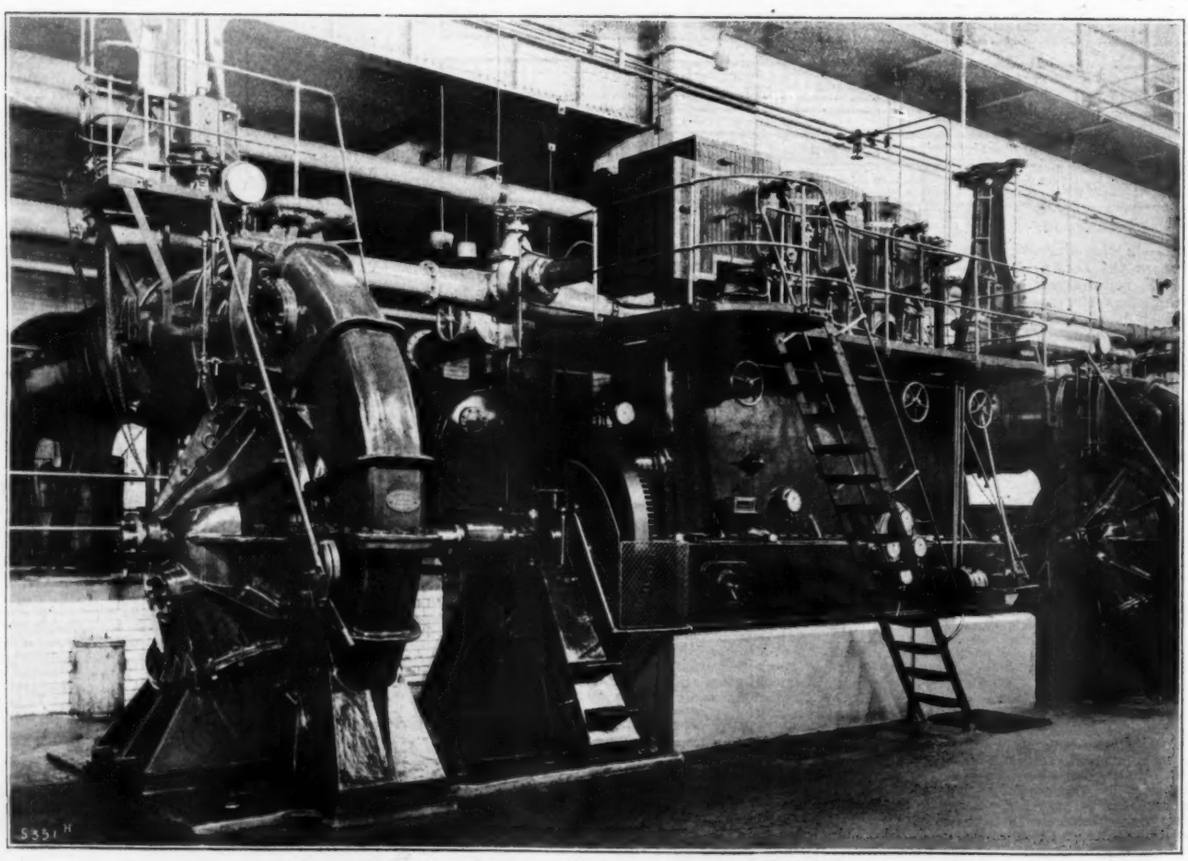


Fig. 9.

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UNITED STATES: For Subscriptions, New York: W. H. Wiley, 432, Fourth Avenue.
For Advertisements, J. S. Allan, 508, Stratford Avenue, Bridgeport, Conn., U.S.A.

ADVERTISEMENT RATES.

The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

SUBSCRIPTIONS, HOME AND FOREIGN.

REVISED RATES.

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Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

All accounts are payable to **"ENGINEERING," LIMITED.** Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford-street, Strand, W.C. 2.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3633 and 3634 GERRARD.

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With a Two-Page Plate of TRIPLE-EXPANSION PUMPING ENGINES FOR THE LONDON COUNTY COUNCIL.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 371.

ENGINEERING.

FRIDAY, APRIL 5, 1918.

INDUSTRY AND THE EDUCATION BILL.

THE Education Bill, which has passed its second reading in the House of Commons and is to be considered in Committee of the House at an early date, has been described as the "Magna Charta of the youth of the nation," and rightly so, because it proposes extensive changes in order to give the fullest opportunity to all for the development of their mental capacities. The general principles underlying the whole scheme are universally approved, but in view of the far-reaching effects of the scheme it is important that there should be a closer approximation to agreement upon all details. The President of the Board of Trade cannot help being gratified at the results of the investigations of such a representative body as the Federation of British Industries, who sent a series of most practical inquiries to all manufacturing firms throughout the country, and received over 2,000 replies. These at once afforded to Mr. H. A. L. Fisher a clear indication as to the line of thought of industry, and the report of the committee, of which Mr. R. T. Nugent was chairman, affords gratifying indication of the broad sympathy of industry with the Government proposals and promise of practical help—administrative and financial—in their realisation.

There is, however, a clearly-defined line of divergence between the Government scheme and the views of industry. The end sought is the same, and, because of this, it is to be hoped that Mr. Fisher will, when the Bill comes before committee, give careful consideration, not only to the views of the industrialist, but also to the interests of manufacture when peace is won. The differences are really dictated by the difficulties of factory management. To begin with, the problems in all works will be intensified by the transfer from war to peace production. Nor will their solution be facilitated by the imperative need for immediately increasing the productive capacity of all establishments, in order that the work of reconstruction of material may be expedited and the revenue of the country augmented so as to reduce the debit side of the national balance-sheet. The ideals of the educationist are accepted, because everyone, and particularly employers, realise that they are not only practical, but will ultimately be of great national and industrial value. The machinery for their realisation, however, must in some measure be brought into harmony with manufacturing conditions, at all events for a short period after the war. This is largely a matter for arrangement, and the report of the Federation of British Industries is so logical that the claims they make, both from the point of view of temporary arrangement and of permanent organisation, need not materially disturb the fulfilment of the ultimate aims of the education authorities.

We are glad that the Federation of British Industries support Mr. Fisher's view regarding the status of the teaching profession. The full success of educational reform is dependent upon this very essential preliminary step. In the first place there must be a great increase in the number of teachers. The Federation put the size of classes, even in elementary schools, at a maximum of forty, and in the secondary schools considerably lower. In the second place, the emoluments must be increased. This, however, will not of itself ensure that the right class of teacher will be secured. The Federation consider that, as soon as practicable, no one should be selected for any post in the teaching service, other than the instructors of infants, who has not had a full secondary education followed by university training, given, if possible, at a residential university where the student mixes with those destined for other professions and is subject to influences whereby his views and outlook upon life may become broadened. It is remarkable that practically all the firms replying to this question approved this proposal. In order that there should be a wider field for promotion it is suggested that there should be greater centralisation of control in larger areas. The teachers also should be, like the civil servant, prohibited from taking part in any political or similar organisation; they should have ample leisure and recreation to provide against staleness; that special classes, summer schools, and arrangements for the development of new methods to enable teachers in their free time to qualify as specialists in particular subjects, should be extended. These proposals will meet with general acceptance.

Regarding the boy and his future, it is gratifying to find universal acceptance of the proposal that the age for compulsory education should be increased to fourteen years. When one recalls the number of half-time boys engaged in various industries, particularly in textile factories, it is a remarkable fact that only five out of the 2,000 firms consulted opposed this increase in age. The Federation, however, differ with the details of Mr. Fisher's scheme for boys beyond this age. Indeed, their view is that at twelve boys should be divided—and here it may be interpolated that the Federation do not, in their report, deal with girls, except to state that where education is vocational, domestic life rather than handicraft should be considered. As regards the boys, the proposal of the Federation is that at twelve there should be a division, the more, promising lads going straight to a secondary school with the object of commencing a full course of whole-time secondary education covering a definite period of four or five years, or alternatively, to a junior technical school, with the object of undergoing a special full-time technical and vocational training, calculated to fit them for the particular industry which their parents desire them to enter, and with a curriculum extending to three years. This, of course, would necessitate a great increase in the number of junior technical schools, particularly in industrial districts. The less promising boys are to continue at the elementary school until they are fourteen years of age, receiving during the last two years a more general training, calculated to develop their character, general intelligence and powers of observation rather than to increase their knowledge on educational subjects. These, obviously, are intended to be members of the "file" of the industrial army. The only serious objection that can be raised to this proposition is that boys disclose their full potential mental capacity at varying ages—even later than girls—and that a considerable number do not show full promise until the age of adolescence. The educationist, therefore, has some reason for the proposal in the Bill that from fourteen to eighteen years of age there should be a definite proportion of time given up per week to education. The Federation, however, quite reasonably reply to this argument by pointing out that boys who develop later could then proceed to the technical schools, and that, for this reason, considerable elasticity should be retained in the case of boys who leave school at fourteen and continue education at voluntary continuation classes after they have begun to work. We can see room for difference of opinion on this point, but the difference is not irremediable. The Federation recommends the utilisation of

part-time continuation schools in some industries, notably for those who expect later in life to fill posts as foremen, leading hands and overseers, whom it would be very undesirable to separate for any considerable term of years from the industry in which they eventually have to make their livelihood. This system, they admit, would be particularly valuable in some industries, notably the textile, motor, electrical, lace, explosives and chemical trades, and in many branches of the engineering, iron and steel trades. But they point out that the proposal of the Bill—that up to eighteen years of age all boys should be required for eight hours per week to attend classes in working hours—would seriously dislocate the works organisation, especially as a very large proportion of the employees are under the age of eighteen. This is found to be the case in Germany, where the regulations for establishing such a scheme provided for a compulsory minimum of two hours per week and a maximum of eight hours per week, between which limits power was given to make arrangements locally. The only other alternative would seem to be to institute a half-time course for a period of years, with a double shift of boys in each factory, the school hours being arranged conformably.

The preference of the Federation is for applying special training to the boys of higher potentialities so far as mentality is concerned: 85 per cent. of those replying approved of all-time training for the few of exceptional promise. This view, too, is supported by the fact that the openings for the higher trained youth are comparatively few. As regards the contention that this precludes the achievement of the ideal of equal opportunity for all, the Federation contend, that the preferable course is to provide equal opportunities as between the able child of poor parents and the able child of rich parents. Consequently they attach great importance to the early selection of the more promising children for training at the secondary school and the junior technical school. At these institutions they propose that provision should be made to recompense parents to some extent for the loss of the earning power of their children, in order that those selected should pursue the course to the end. Inducements should be offered to parents, by provision of the entire educational expenses of the child, by allowing a graduated sum per week to any parent making a declaration of the need of such assistance, and by rendering parents allowing children to leave, without adequate reason, before the completion of the course, liable to refund the money which had been granted to them. There is certainly much to be said for this alternative system, especially as it involves the minimum interference with works management, a point regarding which the President of the Board of Trade does not seem to have given full consideration in his aim to achieve the highest ideal from the point of view of education.

The divergent views between industry and the Education Department thus clearly marked are worthy of careful consideration in order to find a course which will give the nation the necessary highly-skilled leaders, not only in craftmanship, but in initiation, technical skill and management. As we have said, the views of the Federation are the more worthy of conciliatory treatment because of their unity of aim with the education authorities.

Industrialists are certainly prepared to make concessions to advance the educational scheme of the Government. They are willing to adapt, as far as possible, the organisation of their factories, but as intensive production is of vital importance it is necessary that this side of the question should be fully considered. Industrialists, too, are ready to help the Government financially, as well as in collaboration, in the management of any educational reform. We have time and again enforced the view that there is a lack of co-operation between industry and the educational authorities, and the Federation of British Industries does well, in its report, to enforce this view. They recommend that employers should share in the expense of the higher education of those likely to enter their particular branch of industry. Such share should be voluntarily given, and will, we are sure, be liberally given; but it will be an advantage if representation upon educational boards should be granted to employers. This would not only be right, but a great gain, as employers' associations would be brought into more direct contact with the educational authorities of their respective areas, and would be able so to direct education, not only towards improved production but towards the higher culture of the people. There is a great tendency to regard the employer as an advocate of materialism in education and too little recognition of his view that broad liberal education is conducive to the development of the human side, which is an important element in the amicable, and therefore efficient, control of industry. Were employers fully represented on all education boards they would be encouraged to appoint an official skilled in educational problems to represent them, to assist in guiding the educational organisations of the districts, and to correlate the effort of the teacher in finding suitable appointments for all his pupils. The Federation, indeed, consider that there should be an appointments board or similar organisation at every university and every technical school of university rank, associated with some central clearing house, to which manufacturers could apply for the official whom they desired to appoint. Such a central bureau would set out lists, prepared from the universities and technical schools, of all their graduates, with some indication as to their training and general suitability or adaptability for different posts. With such a system it would be easy for employers to obtain the officials they desire, and above all it would be a guarantee that time, money and effort spent in acquiring knowledge would be rewarded with a suitable lucrative appointment at the end of the course. This would be an advantage which does not at present prevail, and the absence of which involves disappointment on the part of many aspirants to appropriate posts in industry.

BRITISH CHEMICAL STANDARDS—IRON AND STEEL.

A scheme which has been in active operation for about two years, following a large amount of preliminary work carried out by Messrs. Ridsdale and Co., Laboratory and Technical Bureau, Middlesbrough, has had for its object the preparation of chemical standards of iron and steel. These standards have been prepared in the interest of science by an informal association of voluntary workers, including public analysts, railway chemists representing users and works chemists representing manufacturers, and up to the time of writing many standard specimens of different steels have been distributed throughout the country. With every portion of standard metal there has always been issued a report showing its contents and stating the method followed by each analyst in determining the contents, an idea for which the promoters are indebted to the United States Bureau of Standards. Each standard has been tested by several chemists of standing, representing different districts and sections of industry, so that by this means the standards have automatically obtained an inherently authoritative value. The scheme has not depended upon any grant or subscription, but the endeavour has been to make it ultimately self-supporting, and pending this, the promoters have, so far, undertaken all financial risk in conjunction with it. At the same time, the scheme was not being conducted with a view to profit, and the prices of the standard specimens have been kept as low as possible to popularise their use. The somewhat unusual arrangement thus followed, which was necessary in order to proceed rapidly, has as might have been expected called forth some criticism; as a whole, however, such criticism has been of a mild nature.

With the object of placing the scheme on a more firm basis and to facilitate the further spreading of the movement, a meeting of the co-operating chemists who had assisted in the work of standardisation—a representative gathering from various parts of the country—was held at York, on February 22, under the chairmanship of Dr. J. T. Dunn, public analyst, Newcastle-on-Tyne. Mr. C. H. Ridsdale, one of the promoters, in explaining the scheme, stated that all the co-operators were firmly united in their desire to bring about the general use of chemical standards of analysis of iron and steel, or, in other words, the unification of analysis of these metals, and the meeting had been called with a view to further this object. In a short time, considering the magnitude of the work, they had obtained, prepared, standardised and issued six of the most urgently needed standards of steel. These were basic steel of dead soft and of two special qualities, an acid open-hearth steel having 0.68 per cent., and one having 0.91 per cent. of carbon and a nickel steel. Five or six more standards were, at various stages, well on the way. The standards had been prepared so as to be thoroughly homogeneous and, with the exception of one, in sufficiently large quantity to be available for a considerable period, which was a necessity if a standard was to be of practical use. The standards had each been tested by eight to 13 chemists, and, as above stated, a certificate showing the results of the method followed was issued with each standard specimen. This fact, he added, invested the standards with an authoritative value beyond dispute; over 100 works and public laboratories had adopted them and there were many other indications of the highest appreciation.

The only demand which had been made on each co-operator was his contribution in the shape of actual analytical work. To the best of his (Mr. Ridsdale's) belief, the United States Bureau of Standards, now a very large institution, was in the first place due largely to the efforts of a railway chemist, Mr. A. Ladd Colby, and a few equally earnest men associated with him in the pioneer work. In the present instance of the British Chemical Standards for Iron and Steel, in order to carry out the actual initial work rapidly, without losing time in following up all the proceedings which generally surround the formation of an association, they had resolved to rely mainly on private enterprise, and he with his son decided to take the initiative, with the result that the scheme was set on foot, "on a short cut" as it were, but with all the essentials which gave standards their real value. The method thus adopted was an unconventional one, but it was also highly elastic and quick in its action. He wished, however, to emphasize that they had undertaken this work primarily for a scientific object, namely, the supply of chemical standards of iron and steel at a low rate in order to popularise them, and not from a commercial point of view. The issue of such standards by them was, however, in no way a private undertaking except as regarded the financial risk, which was borne by them alone. Their desire never had been to run the scheme, so far as the general conduct of affairs was concerned, by their own unaided judgment; on the contrary, from the very outset, the opinion of chemists of standing all over the country was taken, not only as to the desirability of the effort, but also as to the standards which should be dealt with first, and opinions had been constantly taken since by correspondence and interviews. The movement had grown so quickly and to such an extent that the promoters now felt the time had arrived to take the further advice of all the co-operators, and also their views as to whether the separate members should organise more closely, to form an association or an acting committee with a view to taking over the full management and the financial risk. Another matter on which the co-operators would have to express their opinion was as to the attitude to be taken towards the standard movement of the Iron and Steel Institute, which was stimulated into activity after the co-operators' own scheme was already an accomplished fact and, also, largely as a direct outcome of it. The Iron and Steel Institute had freely acknowledged that such was the position in the meetings of their No. 5 Committee to which they had allocated the dealing with standards.

The points raised were fully discussed at the York meeting, and the two following resolutions, framed by the chairman, Dr. Dunn, and by Mr. Dufty, representing Messrs. Sir J. Jonas, Colver and Co., Limited, Sheffield, were accepted. First:

"That additional chemists from the principal works and other laboratories of the county be approached by the co-operating chemists individually and invited to co-operate; it being clearly

explained to them that this is a temporary measure for the purpose of meeting the present need for further standards under the arrangements already in active operation, without unduly straining the present workers; and at the same time rendering the body of co-operating chemists still more widely representative and authoritative, pending the time when the Iron and Steel Institute No. 5 Committee have actually reached the stage of producing standards; and that should that body then wish to adopt and take over the standards issued by them and those in hand, on equitable terms, they should be prepared to cease work in favour of, or be absorbed into that Committee."

Second: "That on sending out circulars announcing the existence and the prices of standards, and giving a list of co-operating chemists, Messrs. Ridsdale and Co. be entitled to state that—'These standards are issued by Messrs. Ridsdale and Co., under the auspices of the body of co-operating chemists, who have gone into the cost of producing the standards and approve of the prices charged for them as just sufficient to cover the cost.'"

THE BIRMINGHAM MUNITIONS AREA.

(*Concluded from page* 348.)

Guns.

Guns are being built all over the Birmingham area. They are to be seen in every stage of manufacture. This is very remarkable when we remember how specialised a trade this has always been, and how it has been understood that it could only be conducted by experts with long years of experience and the highest scientific knowledge. This war should strike a staggering blow at the old fetish, the "trade secret." It has shown that manufactures can be successfully carried on by firms which are entirely new to them if they have some assistance in the early stages, and that most of the carefully-guarded secrets can be penetrated by a reasonable amount of scientific knowledge and some common sense. If we wish to compare the rate of progress between the methods of concealment and those of publicity and discussion, we have only to consider the conditions of the non-ferrous metal manufacture before the creation of the Institute of Metals and at the present time. At the earlier date there were many firms who had stumbled on successful methods of working, but who did not know the *raison d'être* of their processes and therefore did not dare to try to improve them. They remained in a condition of stagnation which was a block to all progress. But within a very few years this has given way to more or less exact knowledge. In most works in the Birmingham area we now find chemists and metallurgists armed with pyrometers, micrographic apparatus, and testing machines, and above all with the spirit of research, and progress is now rapid and continuous. The race is no longer to the reticent but to the swift, and the old trade secret will rapidly become a vanishing asset. The firm which appreciates the significance of the latest discovery and acts upon it will take the lead and keep it. At the same time it is only just to acknowledge the patriotism of those who have freely put their experience at the disposal of possible competitors for the sake of national safety. It is the first step that costs in all undertakings, but in war the early stages may be ruinous if a spirit of obstruction is allowed to prevail.

It would be tedious to continue to mention the firms whom we have seen making the various munitions. They are a small minority of the whole, and, indeed, we have only done so in the previous part of this article to give our account of the activities of the Birmingham area a greater air of reality than it would have had if it dealt entirely in generalities. It is impossible, however, to speak of the guns constructed in this neighbourhood without direct reference to the Coventry Ordnance Company. This is one of the great gun-making firms of the country which had been in existence for a considerable number of years, and were ready to assist the Government at the very commencement of the war. Their plant has, however, been considerably extended during the past two years, and now is turning out aeroplanes and fuses in addition to guns. Every kind of gun is made in these works and every one of the well-known processes of gun-making can be seen. A gun tube was oil-hardened for the benefit of the visitors, and one wondered how many times this particular tube had taken part in the function before. It is understood that nearly 50 per cent. of the screw gauge output of this country is now produced at these works. It was a fortunate thing for this country that all our great munition firms had survived the official neglect to which they had been subjected by the War Office, and were ready to serve as the necessary nucleus of an enormously increased output. Had they not been able in past years to secure a good deal of foreign trade this would scarcely have been possible.

There is one weapon the mention of which always conjures up visions of splendid bravery combined with marvellous skill, and that is the Lewis gun which is found on every aeroplane. We published a full account of this in our issue of November 8, 1912, but it has undergone modifications since, of which it is not desirable to speak in detail. The salient feature of it is that it is air-cooled, and hence it is lighter than any machine gun with a water jacket. The gun complete weighs only 25¼ lb., and can be carried by one man. It embodies the Maxim principle that the breech is opened and the new cartridge inserted by the explosion of the previous cartridge. It was the invention of this method of operation which rendered the machine gun a really serviceable military weapon. Previous to the Maxim's design a slow cartridge might be extracted before it fired, and then the explosion took place among the mechanism with disastrous results. It is only in principle that the Lewis gun is cognate to the Maxim; in construction it is quite different. The motive power is obtained by letting a portion of the gases behind the bullet escape through a port in the side of the barrel and impinge against the head of a free-moving piston, or plunger, which is driven by it against the force of a spring. The motion of the piston is utilised to unlock the breech bolt, feed in a new cartridge, relock the breech bolt and fire. This action can take place 600 times a minute, but if there should be a delayed cartridge the mechanism will pause until the bullet has nearly reached the muzzle. The cooling of the barrel is effected by adding to it a very large cooling surface of aluminium, and inducing all over this a very active circulation of air. Aluminium is chosen for the purpose on account of its high specific heat, great conductivity and low specific gravity. Over the steel rifle barrel, and fitting it very closely is a jacket of aluminium. This jacket has 17 radial fins nearly the length of the barrel, and around the tips of the fins is a thin tubular steel casing, the muzzle end of which extends at reduced diameter beyond the end of the jacket and barrel. To the end of the steel rifle barrel there is attached an expanding nozzle, which, of course, lies within the above-mentioned tubular casing. The purpose of this nozzle is to set up an ejector action at each discharge, and to draw a powerful blast of air through the passages formed by the fins and the tubular casing. These fins present quite a considerable surface, and the heat generated by the explosion in the barrel is rapidly conducted into them, and then washed away, as it were, by the flood of cold air drawn between them. This method of cooling is perfectly efficient in all climates.

The cartridges are carried in magazines which resemble a wheel with two sets of spokes, the cartridges forming the spokes and being arranged in two parallel layers. A magazine is dropped on to a stud standing vertically on the barrel just in front of the breech pieces, and it is rotated step by step at each discharge. At each motion a cartridge drops out of the magazine into the chamber and is then forced forward by the bolt into the barrel. The magazine holds 47 cartridges, and these can be fired singly, or in bursts, or the whole magazine can be emptied. The firing continues as long as the trigger is pressed, and until the magazine is exhausted. The substitution of a full magazine only takes six seconds.

The Lewis gun is manufactured by the Birmingham Small Arms Company, a firm known all over the world for rifles and bicycles. Its career, since its inception in 1861 for the production of muzzle-loading rifles, has been one of steady extension, but since the war it has grown suddenly and enormously, until now it has a capacity for 1,000,000 rifles and 50,000 machine guns a year. The cycle department is now largely engaged on the manufacture of aircraft component parts, 18-pounder shells and other munitions. The factory alone covers a total area of about 24 acres, many of the buildings having four stories, and being the best lighted storied shops we have ever seen. The side walls must be glazed over 70 per cent. of their area. The machine shops erected since the war represent about 2 miles of shops 60 ft. wide. A very considerable portion is occupied by the Lewis gun, and it would be a fascinating task to describe the tools and jigs that have been devised for its manufacture, if it were permitted. They represent a vast amount of thought and ingenuity, and are notable contributions from the Birmingham area to the prosecution of the war.

The name of Hotchkiss has been well known in connection with rapid-firing guns for many years, and on the outbreak of war the Société Anonyme des Anciens Etablissements Hotchkiss set up branch factories, two at Lyons and one at Coventry. This latter has been of immense value to us, for we were badly provided with machine guns at the commencement of the war. The works are on a large scale, and the output is of a corresponding magnitude.

Projectiles.

After a week in the Birmingham area the sight of shell grows monotonous, not to use a stronger term. We have already mentioned how zealously the smaller firms have assisted in its output, and what valuable service they rendered in the early stage of the war. But when immense new works were built and equipped specially for projectiles the output was increased enormously. Now wherever one goes there are piles and piles of shell of all sizes; there are workshops of great length and many bays all turning out shell, and thousands of employees have spent a year or two repeating a single operation on a single size of projectile. One shop alone completes more than 100,000 18-lb. H.E. shell per week, and the aggregate total of the district can be safely put at several millions. More definite figures may not be given. Generally speaking, the processes are identical in the main, and have been very fully described in American papers which circulate here. There are, however, variations in tools and methods even in the best-equipped shops, and it would be a fascinating task, if one had the time and opportunity, to make a critical survey of all the different plans and devices, and thereafter to get out a standard series of operations. However, this is not the time for great changes when affairs are going well, and more good would probably be done by the publication of costs to enable each firm to see how far they were from achieving the most economical results. As it is there is constant pressure exerted by the Ministry of Munitions to reduce prices, and it may be safely stated that a reduction of 50 per cent. has been made since the war commenced. One of the first acts of the committee in 1915 was to organise a National Shell Factory in Birmingham designed to produce 5,000 H.E. shells of 4·5 in. diameter per week, but this limit has long been passed, and a number of 9·2-in. shells added to the output. This factory was located in the premises of the Midland Railway Carriage and Wagon Company, and in addition to the plant above indicated arrangements were made for finishing a still larger number of shells partly machined at the works of contractors who could not undertake the entire process. A fuse and primer department was also instituted to assemble fuse parts manufactured by contractors in the area, and to repair primers returned from the front for renovation. There is also a gauge department to supply the needs of the district; this has done most important work. The total number of employees is 2,350, who attend about 620 machines, and of these hands 80 per cent. are women. The average weekly wage is 6,500*l.*, exclusive of war bonus.

Wagon works are well adapted to shell manu-

facture, and accordingly we find that another firm, the Birmingham Railway Carriage and Wagon Company, Limited, in 1915 reorganised their railway wheel-forging and machining plant so as to adapt it for the making of shell, of which they have provided a continuous supply, the type being 4·5-in. and 6 in. H.E. howitzer.

Nowhere in the Birmingham area, however, is the manufacture of shell seen to greater advantage than in the Works of the Austin Motor Company, Limited. More than 2,000,000*l.* has been spent on this plant since the war began, and all of it is bearing abundant and excellent fruit. Early in the war Sir Herbert Austin undertook to turn out 1,800 shells of 9.2 in. diameter per week, but very shortly he attained to 4,500. Then he contracted to give the Ministry 12,000 shells of 8 in. diameter per week, and rapidly carried this figure to 50,000. In addition to this output, there is a large works which is constantly engaged on 18-pounder shell, and of which the output runs well into six figures. One leaves such works with a profound sense of the immensity of modern warfare, and of the demands it makes not only on the brains and labour of the nation, but on its financial resources. The output, vast as it is, is only a rivulet in the great flood of munitions which is pouring out of this country into France, Greece, Italy, Palestine and Mesopotamia, and which must continue to flow for very many months. Eighteen-pounder shell have been made in numbers which aggregate millions in the works of the Wolseley Motors, Limited, in Birmingham, and one might continue the list almost indefinitely if it were worth while to do so. Enough has been said to show that in regard to the most deadly and essential missile of war the Birmingham area is producing a crop so large and so varied that it is difficult to grasp its full significance.

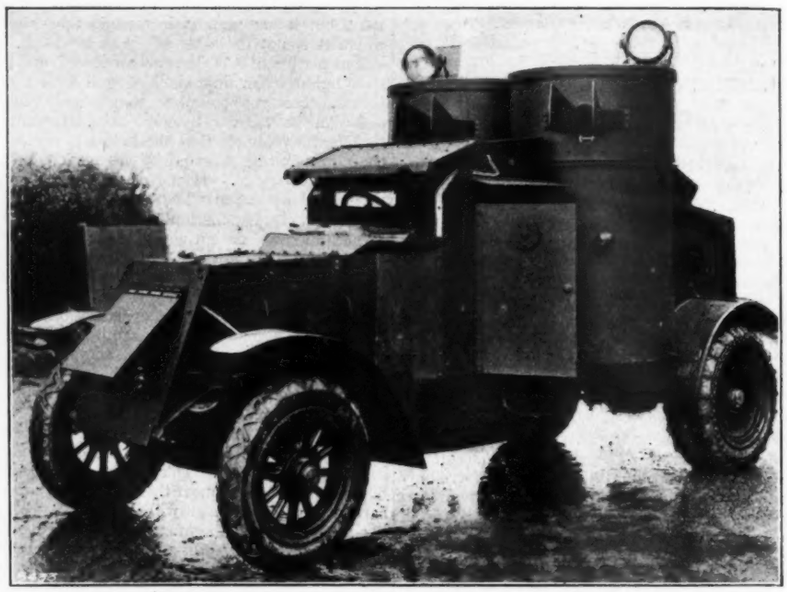
The British Army has always placed great confidence in musquetry and rifle fire. As far back as the Peninsular War we astonished the enemy by the accuracy of our shooting, and in the retreat from Mons the Germans found it difficult to believe that we were almost without machine guns, so rapid and overwhelming was the rain of bullets. We had then less than 200,000 men in the field, but now we have at least 20 times as many, and there must have been a corresponding increase in the supply of cartridges. To this Messrs. Kynoch, Limited, of Birmingham, have made an enormous contribution. They had a great advantage over the majority of firms supplying munitions that they perfectly understood their subject and needed neither research nor advice as to how they should extend their plant. During the Boer War they had turned out rifle cartridges at the rate of 2,000,000 a week. At the outbreak of war the company contracted to manufacture 25,000,000 rifle cartridges per week, and have done so at their Birmingham works. Over 2,000,000*l.* have been spent over plant and buildings, and the annual turnover has increased from 1,500,000*l.* to 20,000,000*l.* The output from 1914 to 1917 included 2,275,000,000 rifle cartridges, besides revolver cartridges and 7,500,000 brass cases for gun ammunition. When one compares these figures with the casualties of the enemy one realises what a haphazard affair is war, and how absurdly low is the efficiency of the most accurate and scientific weapons.

EXPLOSIVES.

Most people will remember the attack on Lord Kitchener because of our want of high explosive shell. If he had cared to reply, which he probably did not, he might have explained that we had no high explosive except a small supply of picric acid. Long ago, thanks to the Explosives Committee, this state of affairs was remedied, and now we have several large works turning out T.N.T. in enormous quantities. One of these works is situated in the Birmingham area. The manufacture is exceedingly simple—in the laboratory. But like many chemical processes it is difficult in the works to secure a uniform product in large quantities, week after week. It was a new industry in this country, and had to be worked out from start to finish. Toluene as received now from the gasworks is represented by $C_6H_5(CH_3)$. Trinitrotoluol is $C_6H_2 . CH_3 . (NO_2)3$, and is produced by stirring toluene with nitric and sulphuric acids for a considerable period during which three atoms of hydrogen are displaced, and three molecules of NO_2 are added. But this is an inefficient method of conducting the process, and the more economical way is to proceed from toluene to mononitrotoluol, then to dinitrotoluol, and finally to trinitrololuol. These three stages are compassed in two operations. First the toluene is mixed in determined quantities with sulphuric acid containing 6 per cent. of nitric acid. The whole is agitated for a considerable time until the toluene becomes mononitrotoluol $C_6H_4(CH_3)NO_2$. This is lighter than the acid, which after a period of settling, can be run off. The mononitrotoluol is again mixed with more acid and the nitration progresses until T.N.T. is obtained.

Toluene, although far purer now than in the early stages of the war, contains traces of other substances, some of which are capable of nitration, and some of which are not. Such impurities have to be removed from the fully nitrated product by washing with water, which must of course be hot as T.N.T. is a solid at ordinary temperatures. The washing is done at 90 deg. C. and then after a drying process the liquid T.N.T. is picked up by the surface of a revolving drum cooled by internal circulation. It immediately sets in yellow flakes which are skimmed off by a blade, or doctor, and are then ready for transit to the shell-filling works, where they are again melted and poured into the shells. Since T.N.T. is the safest of all known explosives it is likely to find a wide field of commercial usefulness after the war.

A by-product of the manufacture of T.N.T. is spent acid. The nitric acid has parted with a large proportion of its nitrogen in the process and become nitrous acid, and the sulphuric acid has been largely diluted with water, due to the removal of hydrogen from the toluene. The nitrous acid is first driven off by heat, and is then condensed in towers packed with silica, and dealt with in absorbers. The sulphuric acid is delivered through a pipe line, to another works three-quarters of a mile away, for concentration. It was a very difficult problem to concentrate weak sulphuric acid to the extent of hundreds of tons a day, for the hot strong acid attacks metal fiercely and would rapidly eat its way through a metal pan. A method was devised embodying several recent modifications of the well-known process of concentrating acid in towers. Several brick towers were built of large diameter and some 55 ft. in height, the bricks being jointed with a new acid proof cement devised for the purpose. At the foot of each tower is a large furnace with forced combustion, and the gases are driven up the tower entering at about 1,000 deg. C. The spent acid is sprayed into the top of the tower and falls through in a fine rain passing through the hot gases. In the descent practically the whole of the water is driven off, leaving strong acid which is run out at the bottom. It is, of course, a matter of fine adjustment between the dilute acid and the hot gases to gain the exact result, but this difficulty has been overcome and the process works steadily and well. It marks a most important step in the production of high explosives and replaces the old and slow cascade process. The comparatively cool gases at the top of the tower carry dust and a good deal of acid mist. They are first passed through another tower down which is sprayed weak acid, and thence through a coke-packed chamber where the remaining mist is scrubbed out before they are delivered to the stack.



ARMOURED CAR FOR THE ROYAL NAVAL AIR SERVICE.

The nitric acid is manufactured at the same works from Chile nitrate, the process being old and well known, but carried on with new plant designed to deal with the great quantities required. The by-product is nitre cake, which is used in iron works for pickling in place of hydrochloric acid. The two acids, sulphuric and nitric, are mixed in the required proportions in these works and delivered through pipe lines to the nitration works, there being several sets of pipes between the two works.

The two works cover many acres, and the first sod was cut in in February, 1915; in May of the same year a few tons of T.N.T. were despatched to the filling factories. At that time output was vital to our existence as a nation; economy and efficiency of manufacture were quite subordinate. But at the end of 1915 a great research department was established, and started to work out the processes first on a laboratory scale and then on a small working scale. The actual financial economies which can be attributed to the work of the research department already exceed 190,000*l.*, although the cost of the research does not reach one-sixth of that amount. It is believed that with the experience gained it would now be possible to design and build a factory for the same output at about one-third the cost, and occupying not more than half the area of the present factory. Nevertheless this factory is believed to be by far the cheapest in capital cost per ton of T.N.T. produced of any factory erected during the war, although the sites were far from ideal and more than one-fourth of the capital cost is represented by plant which has been abandoned or scrapped.

Tanks.

An outstanding example of the abandonment of an old manufacture and the inception of a new one is to be seen in a works only a few miles from Birmingham, where the latest type of tank is being turned out with a rapidity and volume which would bring comfort to many a timorous mind if they could be given in detail. Unfortunately military considerations preclude us from enlarging on this subject, but we may, at least, deal with the picturesque side of it as we saw it recently. Adjacent to the works is an old grass-grown shale heap which forms an excellent exercising ground for the new tanks. The sides stand at an angle of almost exactly 45 deg., and up these the machines climb without hesitation. If the ground slips beneath them they simply grind away until they reach something solid. At the top they turn on their own centres, and then they free-wheel down the slope like a boy on a banister rail. Or else they run round the sidelong ground on the crest, tilted at a great angle and looking as if they ought to overturn. At one spot a concreted slope had been prepared. This, for the greater part of the length is at an angle of 45 deg., but near the top the gradient is suddenly increased to 80 deg. for a few feet, and yet, we were informed, a tank by its own exertions and the friendly boosting of one in the rear, had actually succeeded in making the ascent and reaching the summit. We saw a tank crawl on to a platform railway truck, entering it at right angles. It then set itself accurately fore and aft, settling itself into its exact place as naturally and easily as a lady subsides into a theatre stall. The whole of these tanks, with the exception of the engines, are being made in the works in question, and mostly on an area that was grass-grown only a few months ago.

As a contrast to the tanks, with their ponderous weight and their ability to go over the roughest ground, we give on page 376 an illustration of an armoured car constructed by the Austin Motor Company, Limited. These cars have done, and still are doing, excellent service, but, of course, the range of their usefulness is limited. Still, under suitable conditions, the fire from them can be very galling to the enemy, and in rear-guard actions they can play an effective part.

Labour.

Without labour, capital is inert and brains are of little avail. All efforts would have been fruitless unless the workpeople of the Birmingham area had accepted and seconded them. We have already spoken of the sacrifices of manufacturers; how they have abandoned their established trades and have undertaken tasks for which they had no previous training; how they have purchased tools and laid out extensions for which there is only a problematical future; and generally how they have faced a sea of trouble and uncertainty in response to the call of the country. But the effort and the sacrifice has by no means been confined to the capitalist and the man of high technical skill. Workmen and workwomen have shown an equal patriotism. They have flocked into areas in which there was no proper accommodation for them; they have lived crowded together in most indifferent quarters, and this not for a few weeks or months, but for three years. A fit of enthusiasm will enable any of us to laugh at discomfort and hardship for a week or two, but it needs a deeper, a nobler, conviction to spur us to endure hardship not only for weeks and months, but for year after year. And it is not only out of working hours that discomfort has been borne. Certainly in the new shops the welfare of the workers has been carefully studied. There is light, warmth and ventilation, and generally there are excellent canteens. But in the old works it has often been quite impossible to attain these conditions, and operations are sometimes conducted in dark and crowded rooms. In one case our guide asked: "How would you like to pass your days here?" and we wondered if our patriotism would stand the test as well as that of the girls and men we saw so intensely occupied. Female labour in workshops is no novelty in Birmingham. Girls and women have always been employed in thousands in the light trades, and in some parts of the Black Country they have done a great deal of smithwork. But their presence in machine shops is new—there as elsewhere—and to-day there are thousands of female hands at lathes, drilling machines and milling machines. A great many of them are evidently of a different class from the ordinary female worker of the district, and this probably accounts for the rapid way in which they have adapted themselves to such unaccustomed occupations. There are great variations in the percentage of female hands in different factories. This is partly accounted for by difference in manufactures; generally speaking it is light repetition work which is most suitable for women, and in this the proportion rises to as much as 80 per cent. in some cases. But, quite apart from this, it is clear that some firms have carried female dilution much further than others. Perhaps they came in later and had to make use of the labour that was available, or perhaps the manager had more time to devote to the training of women. Whatever may be the reason one often sees men in some shops doing the same work which is done by women in others, and done both well and quickly.

In a tour such as that which furnished the material for this article it was natural to ask often whether there had been much trouble with labour. The answer was uniformly that there had been very little indeed, and that the small outbreaks which did occur might be attributed to causes common to all human nature, and not peculiar to any class. Years of monotonous labour conducted at high pressure must result in jaded nerves and tired muscles, and under these circumstances occasional evidences of irritability are perfectly natural. The unanimous response last week to the request for the renunciation of the Easter holiday, both in Birmingham and all over the country, shows that in spite of work weariness the great bulk of labour is resolute in its determination to do its utmost to win the war.

Conclusion.

It would be possible to carry this already lengthy article to far greater limits, but enough has been said to show the vast efforts that have been made to provide the munitions of war in abundance for our troops. In the Birmingham area alone there are more than 400 firms acting under the superintendence of the local committee, and there are at least nine other such committees in the kingdom, besides a great number of sub-committees. Only a minute proportion of the 400 firms could be seen by the party of visitors, and of those that were viewed we have not been able to mention all. Two of them, the Electric and Ordnance Accessories Company, Limited, and Smith's Stamping Company, Limited, are worthy of separate articles. The former have a vast output of aluminium castings, brass stampings, fuses and cartridge cases, while the works of the latter have been laid out to produce steel stamped forgings on an immense scale, the largest stampings being produced with a certainty and celerity that open a new field in engineering. We have also been obliged to pass over Messrs. Alfred Herbert, Limited, because they are not directly engaged on munitions. Nevertheless, the rapidity and ease with which we have increased our output of weapons to the present volume is very largely attributable to the tools turned out by Messrs. Alfred Herbert, and to those which they were instrumental in obtaining from their friends in America. These tools are to be found in almost every works, and when we make our final reckoning of indebtedness, if ever we do, the nation will find that it owes much to its tool makers in general and to Messrs. Herbert in particular.

INDUSTRIAL NOTES.

The report for March issued by the Steam Engine Makers' Society states that the membership is now 24,500, distributed over 212 branches; the capital is 245,000*l.* and the number of unemployed 2 only. The fourth quarterly report, from October 1 to December 31, 1917, of the Associated Blacksmiths' and Ironworkers' Society, gives the membership on the latter date as 17,238, showing an increase of 955 over the previous quarter. Six new branches had been opened during the quarter ended December 31. The income for the quarter amounted to 10,751*l.* and the expenditure to 6,162*l.* The funds were returned at 61,369*l.* showing an increase of 4,588*l.* over the total at the end of September. The report for March of the United Society of Boilermakers and Iron and Steel Shipbuilders gives the membership as being about 80,000. The seventy-fourth quarterly balance sheet, to December 31, 1917, of the General Federation of Trade Unions, shows a total net membership of 796,130 and a total gross membership of 964,172. The cost for benefit had been heavy compared with previous quarters, amounting to a sum of 10,215*l.*, but after meeting this expenditure and the necessary management expenses, the committee were able to show a balance over expenditure of 7,775*l.*, and this, added to previous balance sheets, showed a total at the close of 1917 of 213,991*l.* The report for February issued by the United Patternmakers' Association shows a membership of 10,152 distributed over 103 branches.

According to news received from the United States, a programme for the settlement of disputes between capital and labour has been submitted to the Labour Secretary, Mr. Wilson, by the War Labour Conference, made up of representatives of capital and labour, with ex-President Taft and Mr. Frank P. Walsh selected respectively as councillors by capital and labour. The Board is to try to settle by mediation and conciliation all controversies having any relation to war activities. In the event of failure of the Board to bring about voluntary settlement the Board shall by unanimous action select an umpire who "shall hear and finally decide the controversy under simple rules of procedure prescribed by the National Board." In the event of inability on the part of the Board to agree unanimously as to the umpire, the name of the umpire shall be drawn by lot from a list of ten suitable disinterested persons to be nominated for the purpose by the President of the United States. The programme contemplates that the National Board in its mediatory and conciliatory action, and the umpire in his consideration of the controversy, shall be governed by the following principles: "There shall be no strikes or lock-outs during the war. The right of workers to organise in trade unions and to bargain collectively and to choose representatives is recognised and affirmed. This right shall not be denied, abridged, or interfered with by the employers in any manner. The right of employers to organise an association or groups and to bargain collectively through chosen representatives is recognised and affirmed. This right shall not be abridged or interfered with in any manner. The employer shall not discharge workers for membership in trade unions or for legitimate trade union activities. The workers in the exercise of their rights to organise shall not use coercive measures of any kind to induce persons to join their organisation or induce employers to bargain or deal therewith. In establishments where a union exists the same shall continue and union standards as to wages, hours of labour and other conditions of employment shall be maintained.

"In establishments where union and non-union men and women now work together, and the employer meets only with employees or representatives engaged in the said establishments, the continuance of such conditions shall not be deemed a grievance. This declaration, however, is not intended in any manner to deny the right or to discourage the practice of the formation of labour unions or the joining of the same by workers in the said establishments or to prevent the War Labour Board from urging or any umpire from granting under the machinery herein provided an improvement of their situation in the matter of wages, hours of labour or other conditions, as shall be found desirable from time to time. Established safeguards and regulations for the protection of the health and safety of the workers shall not be relaxed.

"As to women in industry, if it shall become necessary to employ women on work ordinarily performed by men they must be allowed equal pay for equal work and must not be allotted tasks disproportionate to their strength. As to hours of labour, the basis eight-hour day is recognised as applying in all cases in which the existing law requires it. In all other cases the hours of labour shall be settled with due regard to Governmental necessity and the welfare and proper comfort of the workers. Maximum production of all war industries shall be maintained and methods of work and operation on the part of employers or workers which operate to delay or limit production or which have a tendency artificially to increase the cost thereof, shall be discontinued. For the purpose of the mobilisation of the labour supply with a view to its rapid and effective distribution a permanent list of the names of skilled and other workers available shall be kept by the Department of Labour for information to be constantly furnished, with the co-operation of trade unions, State employment bureaus and Federal agencies. These bodies should be given the opportunity to aid in the distribution of

APPARATUS FOR HARDENING TRAMWAY RAILS *IN SITU.*

THE SANDBERG SORBITIC STEEL COMPANY, LIMITED, LONDON.

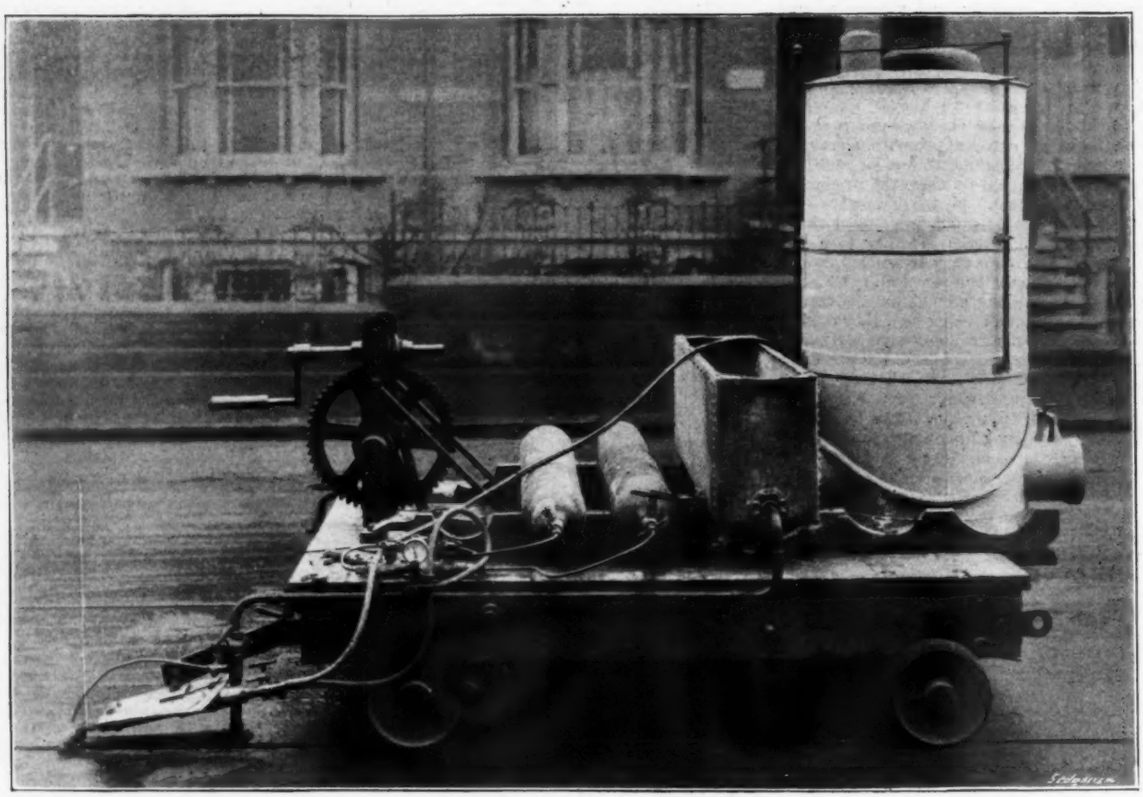


Fig. 1.

labour as necessity demands. In fixing wages, hours and conditions of labour regard should always be paid to labour standards, wage scales and other conditions prevailing in the localities. The right of all workers, including common labourers, to a living wage is hereby declared. In fixing wages minimum rates of pay shall be established which will ensure the subsistence of the worker and his family in health and reasonable comfort.

"The functions and powers of the National Board are to be first, to bring about the settlement by mediation and conciliation of every controversy arising between employers and workers in the field of production concerned in the effective conduct of the war. Secondly, to act in a similar way in regard to controversies in other fields of national activity in which delays and obstructions arise which may in the opinion of the National Board affect detrimentally the work of production. Thirdly, to provide such machinery as may be necessary, by direct appointment of committees or otherwise, where controversies arise, to secure settlement by loyal and conciliatory methods. Fourthly, to summon the parties before the National Board in cases of failure to secure settlement of controversies by local agencies."

The National Board is to meet at Washington. It is suggested that the Board shall refuse to take cognisance of a controversy between employer and employed in any field of industrial or other activity in which there is by existing agreement or by Federal law means of settlement which has not been invoked.

The Amalgamated Society of Engineers, says *The Birmingham Daily Post*, having addressed a letter to the National Society of Amalgamated Brassworkers on the subject of amalgamation, Mr. W. J. Davis, general secretary, has replied on behalf of the Executive Council that his society is federated with the Engineering and Shipbuilding Federation, from which the Amalgamated Society of Engineers, for reasons which were not stated, peremptorily withdrew. By this action the Amalgamated Society of Engineers, it is stated, isolated itself, and was party to a policy of disintegration which has been its own since the Amalgamated Society of Engineers "was ejected at the Plymouth Trades Union Congress for blacklegging a small union of smiths and strikers." The letter goes on to accuse the Amalgamated Society of Engineers of "Prussianism" in relation to members of other societies.

In reference to the attitude of the engineers on the question of man-power, Mr. Davis writes: "The Government at the head of our Empire, the most democratic in the world, sought co-operation with, especially, all metal munition workers. You, with a false dignity again isolated your society, demanding at a time when Britain appealed for your help your pound of flesh . . . You now send up a letter of sickly sentiment about an amalgamation as though you had been the protectors of democracy and defenders of great principles. Your letter is even worse than sickly sentiment, as it came when you desired to brush aside societies representing one and a half millions of workers in favour of a Government recognition of preferential treatment for a minority over the interests of a majority of six to one of your union, thus claiming privilege where you are in a majority and also where you are in a hopeless minority.

"This National Executive, therefore (the letter concludes), invites the co-operation of all kindred trades where the Amalgamated Society of Engineers desires to stop work not to take marching orders except from their own executives, and especially the Shipbuilding and Engineering Federation, with which this society is federated, and in whose judgment it has the fullest confidence. Further, it respectfully requests Sir Auckland Geddes not to yield one privilege to the Amalgamated Society of Engineers over other organised trades."

HARDENING TRAMWAY RAILS *IN SITU.*

In view of the grave difficulties experienced at the present time—due to the shortage of rails and of labour—in the carrying out of any extensive renewals of the permanent way of our tramways, much interest attaches to the process of hardening steel rails *in situ*, which has been successfully developed by Mr. C. P. Sandberg, and which is now being carried out in practice by the Sandberg Sorbitic Steel Company, Limited, of 70, Victoria-street, Westminster. The process has been tested experimentally for some time on the Leeds tramways and elsewhere, but the first application of the treatment under regular working conditions is that which has been carried out on the Croydon tramways, where Mr. E. F. Morgan, the borough road surveyor of Croydon, is applying it extensively.

The problem of applying to a tramway rail, while in place, such a system of heat treatment as will secure an effectively hardened or tempered wearing surface is one which, at first sight, appears to present very serious difficulties, but Mr. Sandberg has succeeded in solving it by comparatively simple appliances, and we illustrate in Fig. 1, on the present page, the plant which is now being used at Croydon. The process consists in causing a flame to travel slowly along the surface of the rail under treatment, this heating being followed by the application of a water jet for quenching, or cooling. In the case of the installation at Croydon the heating is effected by an oxy-acetylene flame; but, of course, other methods of heating may be used if desirable. As will be seen from our engraving, the truck also carries a tank containing the supply of water for cooling. The truck can be moved along the track at a certain defined speed by means of a geared hand-wheel.

We annex, in Figs. 2, 3, 4 and 5, reproductions of three micro-photographs which have been obtained from the Croydon rails, and these show that the hardening is effected to a quite considerable depth, and is thus calculated very materially to add to the endurance of the rails as a whole. The positions in the rail from which the above-named were taken are indicated in Fig. 6. The microphotograph Fig. 5, which has a magnification of 90 diameters, clearly indicates the change in the structure of the rail from the surface inwards. At a distance of $\frac{1}{8}$ in. from the surface there is sorbitic structure as shown in Fig. 2, the Brinell hardness number being about 600. At $\frac{1}{16}$ in. from the surface (Fig. 3) a change from sorbitic to the pearlitic structure is shown, while at $\frac{1}{32}$ in. from the surface there is normal pearlitic structure as seen

HARDENING TRAMWAY RAILS *IN SITU.*

FIG. 2.

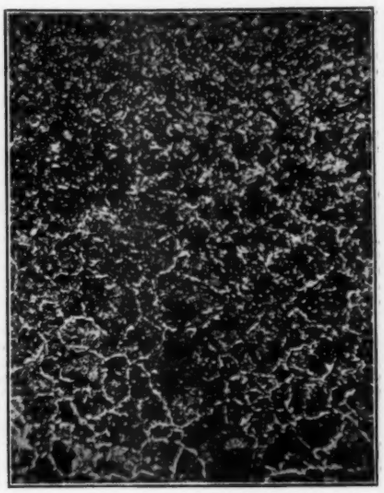


FIG. 3.

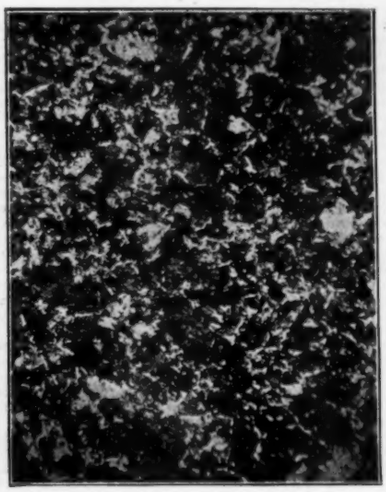


FIG. 4.

in Fig. 4, the Brinell hardness number being about 240. It is found also at Croydon that the process is of special service when applied to the ends of rails which have been battered at the joints. Of course, the hardening treatment does not stop the battering, but it is found that it enables the rail ends to much better withstand the effects of the battering and they become in a short time highly polished, showing that a change of structure has been effected.

We may add that no difficulties have been experienced owing to any action of the heating process on the road pavement adjoining the rails dealt with, and no disturbance of the permanent way is needed. Altogether the experience at Croydon is worthy of the careful attention of tramway engineers, and Mr. Morgan is to be congratulated on having been the first to apply on a practical scale a system of heat treatment of rails which under the present war conditions, promise to prove of special value.

TESTING ELECTRIC IGNITION APPARATUS.

TO THE EDITOR OF ENGINEERING.

SIR,—In connection with the developments in ignition apparatus for internal combustion engines, which have recently taken place in this country, considerable attention has of necessity been drawn to the various methods of testing such apparatus, in order to obtain some criterion which may be used for expressing the merit of any particular magneto or ignition coil.

The article by Mr. J. D. Morgan in ENGINEERING of February 8, page 137, draws attention to certain difficulties which arise in connection with this testing, but the article hardly emphasises to a sufficient degree the importance of discriminating clearly between the testing of the magneto itself and the testing of the magneto in conjunction with the circuit in which it happens to be employed. The magneto, after all, is only a high tension alternator of a very special type, and in just the same way as the output of such an alternator is controlled by the conditions of the circuit to which it is connected, so the output of a magneto is also affected by the conditions under which it is working, and before any definite performance can be laid down for such a machine, it is necessary to satisfy not only the conditions of testing as regards speed, &c., but also as regards the circuit to which the machine supplies its energy.

The normal conditions under which a magneto works are somewhat difficult to define or reproduce, as unlike an alternator or any other dynamo electric machine, it is not supplying current to a circuit with a constant resistance, but one in which the resistance is constantly varying, as except in certain specially isolated cases, the resistance at the moment the first spark occurs is practically infinite, and drops to a smaller figure immediately after the first spark has passed.

The value of the resistance will depend moreover on the conditions prevailing at the spark gap (distance between plug points, compression in engine cylinder, nature of fuel, and temperature of burning charge). It will also depend upon the current which the armature is capable of furnishing, as it is well known that the spark has a lower resistance the larger the current which is passing through it. These conditions, then, are very difficult to define, and still more difficult to reproduce in such a way that definite arrangements can be specified for testing the magneto, which will always give comparable results, truly indicative of the performance of the machine. It is this variable value of the spark gap resistance which makes it extremely difficult to obtain by means of an ordinary thermal ammeter, readings which shall be truly indicative of the capacity of the machine for producing ignition, and which shall be free from errors and inconsistencies due to variations in the conditions under which the tests are carried out.

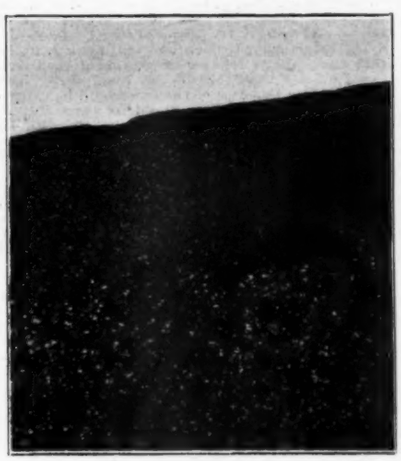


FIG. 5.

WORN RAIL, SHOWING POSITIONS FROM WHICH MICROGRAPHS WERE TAKEN.

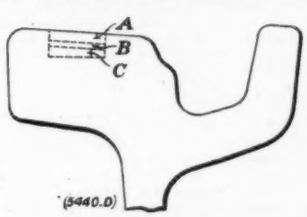


FIG. 6.

In an ordinary magneto working under normal conditions the secondary discharge is produced by a sudden restoration to its original position of the magnetic flux given by the magnet, which is distorted by the primary winding. The primary winding revolves between the pole shoes and the magnet with its two ends short circuited by the contact breaker, into such a position as to produce considerable distortion of the magnetic field, and the field is held in this distorted position by the currents which flow in the short circuited primary. On the separation of the contact breaker points, these currents of necessity cease, and the lines of force immediately commence to return to their original undistorted position. In so doing they cut the primary winding and induce an E.M.F. which initiates a spark in the secondary circuit.

The flux change necessary to produce an initial spark will depend upon two factors (1) the resistance offered to this change by the eddy currents or histeresis of the magneto armature itself, and (2) the capacity of the secondary terminals which has to be charged up to the breakdown voltage of the spark gap before the initial spark can occur. In a well designed magneto, the first of these effects is small, so that if the terminal capacity of the machine is negligible, a small change of flux only (approximately 10 per cent. of the total) is sufficient to initiate the spark between the plug points, so that we have, immediately after the first initial spark has passed, the current established in the secondary circuit with 90 per cent. of the initial flux held in a distorted position by the currents flowing in the spark circuit. The rate at which this flux can return to its original path and hence the continuation of the spark is determined by the magneto motive force given by the magnet, the number of turns in the armature, and resistance of the winding, and the spark gap itself, and if these quantities be known the curve of current in the secondary circuit follows an exponential law capable of calculation.

The time required to complete the discharge will be less, the higher the value of the spark gap resistance. This resistance, which will itself depend, as already mentioned, on several factors, such as the conditions of the gas surrounding the spark gap, and the current flowing in the gap itself, appears to be of the same order as the resistance of the secondary winding itself (in general about 2,000 ohms), which it will be found corresponds to a duration of the spark of considerable length of the order of one or two milli-seconds. This long drawn out spark or flame is probably quite useless from the point of view of producing ignition, but is the quantity which is usually measured on the ammeter which is placed in series with the spark gap, if precautions be taken to protect the ammeter from the effect of the initial rush of current which takes place at the moment when the spark itself is started. It is this first initial rush of current which is believed to be the cause of ignition in the engine cylinder, and it should be clearly understood that the conditions governing the time duration of this initial spark and the current associated with it are quite independent of the characteristics of the magneto itself, and do not in any way depend, as does the flame which follows it, on the resistance of the armature, or the properties of the magnet.

The initial spark is due to the sudden discharge across the spark gap of the energy which has been stored in the cables and other parts connected to it at a potential which corresponds to the breakdown voltage of the gap. This stored energy is free to discharge across the gap at a practically unlimited rate, whereas in the case of the ensuing flame, the current flowing at any moment can never be such that the ampere turns produced by it in the magneto armature exceed those given by the primary winding at the moment of break. This in a magneto of ordinary design limits the maximum possible value of the secondary current at any moment to approximately 0.1 ampere. In the case of the initial spark, when the charged capacity discharges across the gaps, there is no such limit upon the secondary current, which may, and certainly does, very much exceed this value. The greater the capacity connected to the terminals of the magneto, the larger will be the amount of energy associated with the initial spark, and the smaller the amount of energy manifested in the ensuing flame. It seems feasible that to obtain the best results from the point of view of ignition, it would be advisable to make this initial spark as intense as possible and sacrifice the flame to this end, and claims have been made at various

times on behalf of the use of condensers connected to the terminals of the magneto or induction coils, the chief drawback probably being the difficulty of producing a condenser of satisfactory mechanical design to stand the rough handling to which it would be subjected.

It will be evident if tests are made of the current in the high tension circuit, by means of an ordinary thermal ammeter, they will give very divergent results, according to whether the energy given by the magneto is taken out chiefly in the form of a long drawn out flame, or in the sudden discharge of a charged condenser, although the actual energy involved may be the same in either case. If we consider a circuit consisting of a thermal milli-ammeter in series with the spark gap, we see that the total energy given to the complete circuit will divide itself into two portions, one portion heating the milli-ammeter, and the other heating the spark gap. Providing the resistance of both these remains constant, the milli-ammeter would give true readings of the output of the magneto under all conditions, but as has already been pointed out, the resistance of the spark gap decreases very greatly with increasing current, whereas the resistance of the milli-ammeter due to the skin effects associated with the high frequency currents which are involved, has a tendency to rise if the conditions of the spark changes from that of the flame to that of the condenser discharge.

The milli-ammeter will therefore give readings which are very much higher when the spark is of the condenser type than if it is of the flame type, and if these readings are to be taken as indicative of the performance of the machine, it is necessary to specify very clearly the conditions under which the test is to be made.

In Mr. Morgan's instrument no attempt is made to measure the initial current component of the spark. In fact this component is reduced to a minimum by the high resistance of the heater elements employed. For this reason, therefore, the instrument does not truly indicate the capacity of the machine for producing ignition, and in fact it would be very hard to assign a value to this property for any given magneto without at the same time specifying the terminal capacity.

It will be conceded, however, that at all events for machines of similar type, the RMS current as read by Mr. Morgan's instrument will serve as a measure of the initial current rush which can be furnished by any given machine working under given circuit conditions. In this sense, therefore, the indications of the instrument, when used for comparing two machines, are distinctly of value, although its limitations should be borne in mind when machines of different types (*e.g.*, revolving armature and inductor) are under consideration.

A better basis of comparison would possibly be to compare machines on the basis of maximum current at the commencement of the flame discharge, steps being taken to preclude any current due to terminal capacity, as opposed to that furnished by the magneto itself. An instrument which can conveniently measure this has, however, to be invented, and in the meanwhile, Mr. Morgan's instrument is a distinct contribution to the technology of the ignition problem.

I am, yours truly,
E. A. WATSON.

Victoria Works, Coventry, March 16, 1918.

LONG-RANGE GUNS.

TO THE EDITOR OF ENGINEERING.

SIR—Apropos the mysterious bombardment of Paris, it might not be without interest to your readers to know that minute calculations have been conducted by de Sparre, concerning the air resistance to the progress of projectiles in high altitudes and its effect upon the range of large guns. He found that by the elimination of the resistance of the atmosphere projectiles will be carried about 40 per cent. further than would be the case if they traversed a lower stratum of comparatively uniform density of air; thus de Sparre has ascertained that from a German gun of the 381 mm. calibre, which fires a shot of 760 kg. with an initial muzzle speed of 940 m. per second at an angle of 45 deg., the projectile will traverse such a lower stratum of comparatively uniform density for a range of nearly 26 km., and will land at a speed of 344 m. per second. The highest altitude reached in its path is nearly 9½ km., which point is passed at a speed of 284 m. per second.

If the same process is investigated under the influence of decreased density of the atmosphere in the higher strata we find that the highest point reached by the projectile is 12,171 m., at a distance of 21,098 m. from the gun and that point is passed at a speed of 386 m. per second. The projectile on its downward journey increases its velocity up to a maximum of 437 m. per second, which is reached at a distance of 33,940 m. and at an altitude of 5,799 m.; the ground is eventually reached at a distance from the gun of 38,427 m. at a velocity of 433 m. per second, and at an angle of 57 deg. and 56 minutes. This theoretical calculation corresponds tolerably well with actual results obtained with these guns at Dunkirk, where hits have been recorded at 38 km.

Calculations by the same investigator concerning the German ordnance of a calibre of 404·6 mm., which fires a projectile of 920 kg. at a muzzle speed of 940 m. per second for a firing angle of 45 deg., give the following results. The highest point of the path of the projectile is reached at a distance of 21,835 m. and at an altitude of 12,521 m.; at this point the projectile has a speed of 396 m. per second and reaches the ground at a distance of 40,219 m. at a speed of 451 m. per second and at an angle of 57 deg. and 57 minutes. The ballistic tables upon which these calculations are based apply to a temperature of 15 deg. and a barometer reading of 750 mm. For a temperature of 28 deg. and a barometer reading of 740 mm. the path of a 381-mm. projectile would be the same as calculated for a 406·4-mm. one, the distance reached, however, would be 1,792 m. greater; likewise for a temperature of 2 deg. and a barometer reading of 760 mm. the distance reached by the shot would be correspondingly less. From these figures we see that both the temperature and the pressure of the air influence the distance reached by a projectile under otherwise identical conditions.

Your obedient servant,
G. F. ZIMMER.

82, Mark-lane, E.C.3, March 27, 1918.

TO THE EDITOR OF ENGINEERING.

SIR,—Most of the suggestions which have been made as to how the Germans can throw a 9·2-in. shell to a distance of, say, 80 miles, are not practical, but the problem is capable of solution on the following lines. About the year 1860, Mauser, of needle-gun fame, wished to improve the trajectory of the muzzle loaders of his day. He hit on an idea with which he attained his object, but found that with the improved bullet he was now using, a breech-loading mechanism was almost essential; and thus, having invented the needle gun, he found that the improved bullet was after all not a necessity and he discarded it. Instead of using a ¾-in. bullet for a ¾-in. bore he used a ½-in. bullet, wrapped paper round it, so as to give it a diameter of ¾ in., and placed a circular disc of firmly compressed cardboard under the base of the bullet. This combination was then dropped on the powder charge and discharged. Being very much lighter than the ¾-in. bullet the velocity of the combination was a very high one, and as the paper case dropped off as soon as the combination left the muzzle of the gun, the bullet maintained a very high velocity during the remainder of its flight.

This old idea has probably been revived in the modern long-range gun. The Germans are probably using a naval gun of about 15 in. diameter, having an extreme range of, say, 30 miles. The weight of the 9·2-in. shell which it fires would be about 0·22 of that of the 15-in. shell, and allowing 0·11 addition for the envelope, which would have to be a very strong cage, the total weight of the combination would be about one-third of the weight of the 15-in. shell. Its range, after the cage has dropped off, would be about 3 × 30, or 90 miles.

The range could be increased still further, for seeing that the average velocity of the caged shell is three times greater than that of the 15-in. shell, the time during which the bore of the gun would be exposed to the hot gases would be reduced to about 0·6 of the firing duration with the 15-in. shell. Now the length of the gun is limited by the intense heating effect of the incandescent gases, and as the duration of this firing period varies inversely as the mass to be propelled, it is evident that a 15-in. gun could be used, which is three times longer than the original one, then the projectile could be thrown to a distance of 9 × 30 = 270 miles or probably a great deal further, because as it rises to a height of about 70 miles, the main portion of the trajectory is in a comparatively low vacuum. This circumstance suggests the further possibility that the cage might be dispensed with altogether and that a comparatively short shell might be fired to these long distances. Although its loss of velocity, if fired horizontally, would be very great, very little retardation would be experienced during a high-angle flight after the projectile had risen, say, 3 miles above the ground.

Possibly the German long-range gun combines the two principles; it may be less than 15 in. diameter, say 11 in., but much longer than an ordinary gun of that diameter.

I am, Sir, yours faithfully,
C. E. STROMEYER.

Manchester, March 28, 1918.

STANDARD LOCOMOTIVES FOR BRITISH RAILWAYS.

TO THE EDITOR OF ENGINEERING.

SIR,—The spirit of inquiry—largely stimulated by the pressure of events of the last three years—into all questions of national economics has opened up a perspective view fully 40 to 50 years in advance of that which existed in the pre-war times of but four years ago. A process of rapid evolution or quickening in the beam of general intelligence, is taking place, which finds expression in many thoughtful contributions to the technical press advocating reforms and progress of great magnitude in all branches of engineering. In view of the reasoned acceptance of many innovations, it is within the sequence to suppose that the matter of the standardization of locomotive designs should come within the bounds of practical politics.

The figures contained in the following remarks must not be accepted as quite authentic. They are intended to approximate to the conditions obtaining in the suggestions made in several quarters, especially upon the point of economy in production which is collateral with that of design.

An investigation into the number of standards of locomotive units upon the railways of England, Scotland and Wales produces approximately the following results. There are in round numbers 20,350 locomotives employed upon the 14 important railways and 1,650 in service upon the 13 small railways, or a gross total of 22,000. Upon a conservative estimate the average number of standard types upon each railway is 10, or a total number of 270 standard types in general service.

In this connection it is singular to note that the late D. K. Clark—one of the most eminent engineers of his time—in the early fifties strongly advocated the use of five types of locomotives only, as being sufficiently adequate to cope with all general conditions of railway service.

In the Railway Returns for 1913 the significance of the figures 6,305,000*l.*—lumped together as expenditure upon the maintenance and renewals of locomotives for 1912 for the railways of England, Scotland and Wales—is rather obscured by the lack of differentiation and does not permit of analysis, but the not unnatural assumption is that maintenance may be considered as applying to material or details renewed in service, due to breakage and incidental everyday working, whereas renewals may be considered the replacement of units worn out in service, such as new engines and boilers.

Neglecting engines built out of capital account—of which upon the meagre information obtainable there were 556 built by or supplied to the above-mentioned railways between the years 1903 to 1912—the renewals out of revenue, including new boilers, may be taken on an average at 3 per cent. for engines and 7 per cent. for boilers, or in round figures 660 new engines and 1,540 boilers per annum. The whole of this work is constructed, in at least twelve different centres, to many varying designs and involving the use of thousands of different templates and the multiplication of enormous masses of machinery.

The suggestion for standardisation of designs carries the subject forward to an equal object in economy and that is the combination of the twelve locomotive building centres, owned by the railways, into one large concern, situated in a part of the country where electrical power and manufactured material for constructional purposes would be available. Such a concern could accommodate the modern part of the machinery and plant of the existing engine works and be laid out upon lines sufficiently generous to allow of a steady output of locomotives and boilers and also with an eye to the prospects of the growing demand in electric traction, the present works being partly retained for ordinary repairs.

There are several possibilities attached to such a scheme providing arrangements are such as to ensure locomotives being built upon a cost and profit basis. Emphasis is laid upon this provision, as present railway costs of production are fallacious, inasmuch as railways are not producers in the commercial sense of the term and such important items as establishment charges, including depreciation, are but cursorily dealt with in the locomotive accountants' department. All railway companies, large or small, would buy their engines at a uniform price—an important consideration to the smaller companies. At the present time smaller railways—following the extravagant course of building their own engines—are handicapped when compared with the larger railway companies; as an elementary illustration a large railway company in the North, or in the Midlands, accessible to the supply of materials in the immediate vicinity, building a batch of from 50 to 100 engines, will produce upon a cheaper scale than a small company in the South of England building 10 to 20 standard engines.

The output of a large central works would be uniform and continuous, and the elimination of the present small individual manufacturing units, with their attendant fluctuating and wasteful demands, would compensate to a considerable extent for the outlay of capital upon the new works.

A headquarter staff for designing purposes could be established. This staff would also control the experimental research work and the testing plant—both very important items in future rolling-stock economics. They would have direct access to the traffic department for the purpose of mutual consultations upon all questions affecting the establishment of economical designs of standard engines. The importance of the suggestion that the traffic department will have to be consulted upon all questions of design, arises from the conviction that this department will be the predominant partner in all future railway administration, inasmuch as it is responsible for creating the revenue of the railways and, therefore, has a right to maintain a supervision upon the expenditure.

No injustice would be done to the private engine builders outside the railway companies' combine, inasmuch as for a number of years they will be engaged upon Colonial and Foreign work and they would, perhaps, receive a considerable portion of the British Railway Companies' engine work scheduled under capital account.

A further extension of this scheme with infinite possibilities in economy is applicable to all branches of rolling-stock upon the railways of Great Britain.

I am, Sir, yours truly,
S.W.1. March 12, 1918. "PRINCIPIA."

GAS IN MOTOR VEHICLES.—The Board of Trade have issued a notice under the Gas (Use in Motor Vehicles) Local Prohibition Order, 1918, cancelling the prohibition of the use, for driving motor vehicles, of gas manufactured or supplied by the gas undertakings of the Sheffield Gas Company, the Stockport Corporation, the Stockton-on-Tees Corporation, and the Town of Dudley Gas Light Company. The prohibition continues to apply as regards the Portsea Island Gas Light Company and the Tottenham District Light, Heat and Power Company.

EMERGENCY FLEET CORPORATION'S FIRST WOODEN SHIP.—One of the first wooden ships built for the Emergency Fleet Corporation is nearing completion at the yards of the Peninsula Shipbuilding Company, Portland, Ore., says *Contracting*, New York. This was the first of the wooden ships to be launched. She has over-all dimensions of 280 × 50 × 28 ft. and draws 24 ft. 6 ins. at the load water line. The displacement is 6,500 tons and the dead-weight carrying capacity is 4,000 tons. The massive wooden frames at the keel are of two 12 × 26 in. timbers which taper to make a 12 × 24 in. built-up member at the sheerstrake. The two timbers making up the member are cemented together, and dry rot is prevented by the use of Maritimo Coating.

CASTINGS OF ADMIRALTY BRONZE.

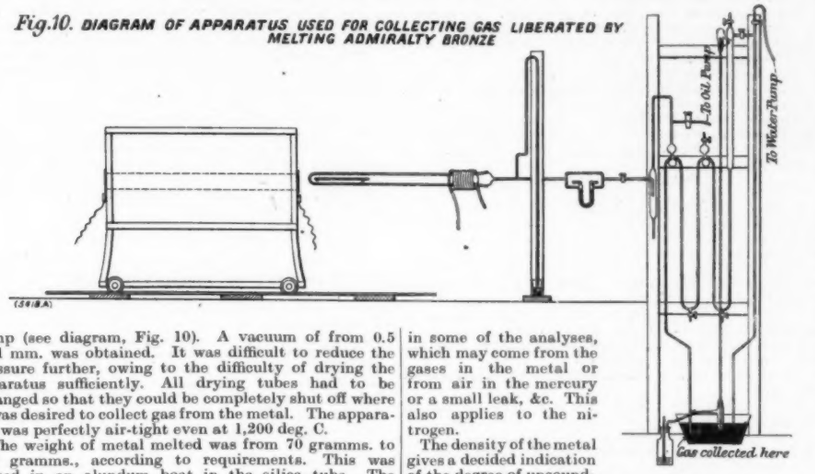
*An investigation on Unsound Castings of Admiralty Bronze (88 : 10 : 2) : Its Cause and the Remedy.**

By Professor H. C. H. Carpenter, M.A., A.R.S.M. (President), and Miss C. F. Elam.

(*Concluded from page 352.*)

It was thought that by comparing the volume and composition of the gases in sound and unsound castings, any differences between them might give a clue to the problem. In order to do this sections cut from the castings were melted *in vacuo*, and the gases given off collected and analysed. The apparatus consisted of a fuzed silica tube, closed at one end, the other end, which protruded 6 in. from the furnace, being connected to glass tubing by means of a greased ground-glass joint. This was kept cool by a spiral of flexible tubing through which water flowed. By means of glass tubing the silica tube was connected to a barometer and an automatic Sprengel pump (see diagram, Fig. 10). A vacuum of from 0.5 to 1 mm. was obtained. It was difficult to reduce the pressure further, owing to the difficulty of drying the apparatus sufficiently. All drying tubes had to be arranged so that they could be completely shut off where it was desired to collect gas from the metal. The apparatus was perfectly air-tight even at 1,200 deg. C.

Fig. 10. DIAGRAM OF APPARATUS USED FOR COLLECTING GAS LIBERATED BY MELTING ADMIRALTY BRONZE



The weight of metal melted was from 70 gramms. to 150 gramms., according to requirements. This was placed in an alundum boat in the silica tube. The furnace was a platinum wound tube furnace and was mounted on rails, so that it could be slipped on or off the silica tube as desired, thus enabling the metal to be cooled quickly or slowly. In this way it was also possible to observe the metal at any moment. Unfortunately owing to the difficulties of manipulation, it was impossible to have a thermocouple actually registering the temperature of the metal. The temperature of the furnace being known, however, it could be kept constant a sufficient length of time to enable the metal to reach that temperature also.

Some preliminary experiments were carried out to ascertain the volume of gas that was likely to be obtained. The metal was heated to 1,100 deg. C. and in some cases to 1,200 deg. C., and maintained at that temperature for half an hour. The gas did not always all come off on the first heat, and sometimes two or even three melts were necessary before on further heating there was no change in pressure. A chill casting was an interesting example of this. The metal was heated until no further gas came off. On examining it after cooling, it had the appearance of an unsound sand casting, the surface had risen and it was full of large blowholes. On heating further more gas came off. Trials were made of a silica boat for holding the metal, but this had to be discarded as bubbles of gas collected between the boat and the under surface of the metal and remained there. The gas could not force its way out even at the reduced pressure, and the character of the solidified metal showed where these bubbles had been. This demonstrates that the gas does not readily escape from the metal. The volume of gas obtained was calculated from the increased pressure, as observed by the barometer tube, the volume of the whole apparatus having been previously determined. There were considerable variations in the volume of the gas obtained from pieces cut from the same ingot, the average volume from a sand-casting poured at 1,445 deg. C. being about 4.5 c.c. per 100 grammes (about 12.5 c.cm.) of metal. A chill casting gave approximately the same amount, and a sand-casting poured at the right temperature generally a little less. The gas began to come off at about 450 deg. C. from a sand-casting; that from a chill casting at about 750 deg. C. The evolution, when once begun, continued regularly up to the melting-point, at which temperature it practically ceased. There was no sudden absorption or evolution at that point. A large proportion of zinc volatilised on the sides of the tube. In some cases only a trace remained in the alloy. There was also a black substance which deposited. On dissolving all the deposit off with nitric acid, sulphur separated, while with hydrochloric acid there was a strong smell of hydrogen sulphide. Probably there is present a mixture of zinc, zinc sulphide, copper oxide and copper sulphide, and free sulphur. There was considerably less sulphur from the alloy made from cathode copper than from any other. As will be shown later, the zinc is chiefly responsible for combining with the sulphur, and deposits on the sides of the tube as zinc sulphide.

The tin does not appear to be affected in this way.

On cooling small beads of metal are ejected. If the furnace is removed so that the tube and metal cool quickly, a film of cupric oxide is deposited on the inside of the tube immediately above the boat, and sometimes also on the surface of the ingot. This only occurs if the furnace is removed while the metal is molten. If the tube cools slowly in the furnace, any cupric oxide so formed volatilises and collects outside in the cooler parts together with the zinc. This suggests that oxygen in some form is liberated on cooling, and that it can be retained in solution even at a pressure of only a few millimetres. It does not, however, make the metal unsound. Any oxygen given off by the alloy, along with the other gases, immediately forms cuprous or cupric oxide and can never be collected as a gas. Either it exists as oxides of copper, tin, or zinc, or it may be formed by the decomposition or interaction of certain other gases present. There is a small amount of oxygen in some of the analyses, which may come from the gases in the metal or from air in the mercury or a small leak, &c. This also applies to the nitrogen.

The density of the metal gives a decided indication of the degree of unsoundness. There are considerable variations in the same casting according to whether the metal is cut from the outside or the centre. Below is a list of the densities of some castings of the composition 88 per cent. copper, 10 per cent. tin, 2 per cent. zinc :—

Nature of Copper and Mould.	Pouring Temperature.	Density.
	deg. C.	
1. Mersey copper, sand	1,445	8·2 8·1 7·79 7·2
2. Cathode copper, sand	1,395	8·34
3. Cathode copper, sand	1,235	8·69
4. Mersey copper, sand	1,137	9·00
5. Mersey copper, chill	1,400	8·73 and 8·8
6. Cathode copper. Nos. 2 and 3 melted *in vacuo*	—	8·85

When it came to collecting the gas for analysis a very much smaller volume was obtained than had been expected from the calculations. It was found that the volume varied according to the time taken in removing the gas. Not only did the volume vary, but the composition varied also. The following are two analyses of gas collected from adjacent pieces of the same casting; in the first the pump was started simultaneously with the heating, and in the second the apparatus was allowed to cool before being evacuated. Hence in the latter the gas was in contact with the hot metal for a considerable time, and its various constituents had a chance of reaching an equilibrium.

	I. Per Cent.	II. Per Cent.
Sulphur dioxide and hydrogen sulphide	15.55	—
Carbon dioxide	3.40	5·79
Carbon monoxide	57.00	41.33
Hydrogen	7.60	40.98
Saturated hydrocarbons	1.97	0.93
Unsaturated hydrocarbons	0.88	1.51
Oxygen	1.22	—
Residual gas, nitrogen	7.83	7.42
Volume of gas collected per 100 grammes metal at 0 deg. C. and 760 mm.	2.17 c.c.	3.65 c.c.

The sulphur dioxide and hydrogen sulphide are estimated together as there is not a reliable method of absorbing them separately when dealing with such small quantities.

It will be seen from the above that the larger volume is associated with a large proportion of hydrogen, whereas the smaller has very little hydrogen and a considerable quantity of sulphur dioxide and sulphuretted hydrogen. This is true for all the analyses that have been done. The facts, then, are these: if, on the one hand, the gas is removed as quickly as it comes off, it has a smaller volume, its chief characteristics being a large percentage of sulphur dioxide and hydrogen sulphide and a small percentage of hydrogen; if, on the other hand, the gas is removed slowly or heated for a long time in contact with the hot tube and metal, the volume is larger than in the former case. There is then a large percentage of hydrogen, and the sulphur dioxide and hydrogen sulphide are either low or entirely absent. It follows necessarily that there are intermediate stages with varying proportions of these constituents corresponding to variations in the volume.

The zinc volatilises when the alloy is heated, and is no doubt responsible for the absorption of the sulphur from the sulphur dioxide and hydrogen sulphide when the gas is left in the heated tube for some time. Even if it is removed as quickly as possible only a portion of these gases is collected. To show this more clearly, an alloy was made containing 89 per cent. copper and 11 per cent. tin, the gas from which gave the following analysis :—

	Per cent.
Hydrogen sulphide and sulphur dioxide	53.4
Carbon dixoide	5.10
Carbon monoxide	27.45
Hydrogen	nil
Saturated hydrocarbons	1.40
Unsaturated hydrocarbons	1.70
Oxygen	1.45
Residual gas, nitrogen	10.50
Volume of gas collected per 100 grammes metal at 0 deg. C. and 760 mm.	1.44 c.c.

It seems likely, however, that the zinc not only reacts with the sulphur dioxide and hydrogen sulphide during the experiment, but that it also lessens the solubility of these gases in the alloy. Below are two analyses of the gases evolved from pure copper (Rio Tinto best selected), somewhat overpoled. In the first the gas was heated to constant volume. In the second it was collected as quickly as possible. They most nearly resemble the analysis of the gas from the copper-tin alloy just given, and since they are so much alike they emphasise still further the important part played by the zinc in altering the volume and composition of the gas collected from Admiralty bronze. In neither of these was there any free hydrogen.

	Gas collected quickly. Per cent.	Gas collected Slowly. Per cent.
Hydrogen sulphide and sulphur dioxide	70.90	61.15
Carbon dioxide	19.60	34.90
Carbon monoxide	4.70	—
Hydrogen	—	—
Saturated hydrocarbons	0.75	—
Unsaturated hydrocarbons	—	—
Oxygen	1.25	1.10
Residual gas, nitrogen	2.80	2.85
Volume of gas collected per 100 grammes metal at 0.3 deg. C. and 760 mm.	4.45 c.c.	5.95 c.c.

In these cases there was not much cuprous oxide in the copper, and very little oxide was found on the tube on heating.

On the whole, a smaller volume of gas was generally collected from the sound metal, but this was by no means always the case, and it was very difficult to make comparisons between them owing to the uncertainty of exactly reproducing the conditions in each case. The only way in which such a comparison could be made was by heating the gases in the tube to constant volume. Sound and unsound metal poured in one case from the same crucible gave 6.44 c.c. and 5.95 c.c. respectively, calculated from 100 grammes metal at 0 deg. C. and 760 mm.

As it was considerably more difficult to ensure the same conditions when removing the gas quickly, owing to different rates of heating and variations in the working of the pump, it seems fairest to compare the analyses of gas samples collected after cooling, when these variations do not matter. The interaction of the gases is not very rapid even at 1,100 deg. C., but provided the metal is maintained at that temperature for a sufficient period the reaction is complete. In all these experiments the apparatus was allowed to cool before being evacuated.

In the next column is given a series of analyses of gases obtained by heating certain pieces of castings until apparently all the gases had been evolved. There is a considerable difference in the volumes obtained, and it will be noticed that the largest volume of all was obtained from a sound casting poured at the right temperature.

The most constant characteristic of all these gas samples is the large percentage of hydrogen. Allowing for probable errors in the analyses owing to the small volumes of the gases—seldom more than 3 c.c. or 4 c.c. and sometimes less—and for variations in the experiments for differences in the preparation of the castings, &c., there is no outstanding difference between the gases collected from sound and unsound castings which would account for the absence of blowholes on the one hand, and the presence of blowholes in the other hand. The gas that shows the greatest variations is carbon monoxide, but there is nothing to indicate that it has any

* Paper read before the Institute of Metals on Thursday, March 14, 1918.

relation to the unsoundness. Taking everything into consideration, it cannot be concluded that there is any gas present in the metal poured too hot that is not in the sound metal, nor does it appear that there is a larger volume of any one gas or gases present in the one than in the other. It does not follow that this is the case when the metal is at different temperatures, and it only applies to the gases when they are collected in this particular way, which represents their equilibrium stable at 1,100 deg. C. under the conditions of the experiment.

Gas heated for half an hour in the apparatus before removing.

Nature of metal	Sand Cast.* Mersey.	Chill Cast.* Mersey.	Sand Cast.† Mersey.	Sand Cast.† Cathode.	Sand Cast.† Cathode.
Pouring temperature ..	1,400 deg. C.	1,400 deg. C.	1,225 deg. C.	1,235 deg. C.	1,395 deg. C.
Sulphur dioxide and hydrogen sulphide ..	—	—	4·64	10·25	2·00
Carbon dioxide	5·79	7·57	9·30	10·01	4·50
Carbon monoxide	41·33	32·38	19·80	20·62	25·20
Hydrogen	40·98	50·19	56·72	52·89	56·95
Saturated hydrocarbons ..	1·97	0·93	1·14	1·00	3·05
Unsaturated hydrocarbons	0·88	1·51	1·19	0·60	0·75
Oxygen	1·22	—	0·87	0·89	—
Residual gas, nitrogen ..	7·83	7·42	6·32	3·98	7·55
Volume of gas collected per 100 grammes at 0 deg. C. and 760 mm.	3.65	2.88	4.08	2.66	3.53

* None of these three was cast at the same time.
† These two were poured from the same pot with about 5 minutes interval.

The fact that the metal is melted *in vacuo* and that the zinc volatilises must have a marked effect upon the gas reactions. For that reason alone it might be fairer to take the gas samples collected as quickly as possible as being more representative of the gases in the metal. For reasons already given, these do not show the same agreement as the others.

Gas removed from the apparatus as quickly as possible.

Nature of copper ..	Cathode.	Cathode.	Mersey.	Mersey.
Pouring temperature ..	1,395 deg. C.	1,235 deg. C.	1,400 deg. C.	1,237 deg. C.
Sulphur dioxide and hydrogen sulphide ..	8.65	15·95	15·55	27·60
Carbon dioxide	15·35	9·20	3·40	6·60
Carbon monoxide ..	21·05	21·60	57·00	41·60
Hydrogen	23·95	31·40	7·60	—
Saturated hydrocarbons..	3·30	3·85	2·95	—
Unsaturated hydrocarbons	2·05	2·60	2·45	2·10
Oxygen	0·90	0·75	1·05	0·40
Residual gas, nitrogen ..	24·75	14·65	9·40	21·70
Volume of gas collected per 100 grammes metal at 0 deg. C. and 760 mm.	—	1.0 c.c.	2.33 c.c.	1.9 c.c.

All the errors of analysis are found in the last figure of the columns, together with the actual amount of nitrogen present. The error is necessarily greater when dealing with such small volumes.

These analyses may be considered in relation to alloys made from cathode copper and those made from Mersey copper. As would be expected, the hydrogen is high in that made from cathode copper. On the other hand, these differences disappear when the gases are collected in the other way, as the previous table shows. As the bronze is liable to be unsound irrespective of the copper used, it follows that these analyses can hardly represent the composition of the gas which makes the blowholes.

It is remarkable that there is no free hydrogen in the copper to begin with, and that it is entirely absent or very low if the gas is removed quickly from the apparatus. Where does the relatively large volume of this gas come from, which appears when the evolved gases are maintained at 1,100 deg. C. in contact with the hot metal for some time? Some of it obviously is formed by the decomposition of hydrogen sulphide, since in all the gases investigated a small volume of the one is always associated with a relatively large volume of the other. Hydrogen sulphide decomposes at 400 deg. C. into its elements after which the zinc unites with the sulphur forming zinc sulphide, and the hydrogen is left free. On the other hand, sulphur and hydrogen combine at a high temperature, making the reaction reversible.

The large volume of hydrogen may be due to the dissociation of water formed by the combustion of hydrocarbons, with a simultaneous formation of carbon monoxide and carbon dioxide. It may be due to the decomposition of certain hydrocarbons yielding two or three times their volume of hydrogen. The nature of the gas is so complex and its possibilities of reacting so numerous that it is difficult to formulate any hypothesis with confidence as to its behaviour at such a high temperature under such exceptional conditions. One thing at any rate is certain, namely, that this mixture of gases can exist in more than one form, each possessing its characteristic volume and composition. It must not be forgotten, however, that the gas mixture with the smaller volume could not possibly change into the gas mixture with the larger volume by merely heating it for any length of time. The presence of the hot metal is necessary, and even this must have a chemical and not a catalytic action.

Any differences in the total volume of gases collected from sound and unsound metal do not appear large enough to warrant the conclusion that the blowholes in metal poured too hot are caused by a total larger volume of gases soluble at that temperature but insoluble at a lower temperature. Nor is there any evidence for stating that one particular gas, which is soluble at a high temperature but comes off as the metal cools to the correct pouring temperature, is the cause. The fact that it is very difficult to extract the gases from this metal, under any circumstances, points to another reason altogether. The explanation which appears most probable to the authors is based on the fact which they have established, that more than one volume and composition of the gases occurring in Admiralty bronze is possible. It seems reasonable to suggest that the sudden change of temperature in the alloy, due to pouring at a very high temperature, is sufficient to cause a reaction or a decomposition of certain of the gases, with the formation of another gas mixture with a relatively large volume which is insoluble in the alloy. At a lower temperature the gases are not so susceptible to this change, and those present in the metal remain in solution. Comparatively little work has been done on the reactions of gases at high temperatures, and practically nothing at the casting temperature of Admiralty bronze, so that it is impossible to predict the action of the very composite gas which has been found in this metal. Pending this no complete scientific explanation of the unsoundness liable to occur in Admiralty bronze can be put forward.

PRACTICAL CONSIDERATIONS.

It is clear from the foregoing investigation that, provided Admiralty bronze (88 : 10 : 2) is not poured at too high or too low a temperature, there should be no difficulty in obtaining sound castings. The upper limit of 1,270 deg. C. and the lower limit of 1,120 deg. C. fixed by Karr and Rawdon should be borne in mind in this connection. Although the authors have not tested these precise limits their results are, generally speaking, in harmony with them. The problem therefore is essentially one of temperature control and nothing else. How can this best be practically achieved?

Three ways at any rate suggest themselves for consideration:

1. To melt and cast the alloy so that no contamination by gases is possible.

2. To regulate the temperature of the melting furnace so that the upper limit of 1,270 deg. C. is under no circumstances exceeded.

3. Always to determine the temperature of the alloy before it is poured and to cast it within the safety range.

Method 1.—This appears to the authors the least promising of the three. It might be considered on *a priori* grounds that success could be reached by melting the alloy in an electric furnace. The only certain way of excluding gases from the outside in this case would be to melt and cast *in vacuo*—a method which can at once be ruled out on practical grounds. Even this, however, if successful from this standpoint, would not constitute a complete solution, for the reason that it takes no account of the gases contained in the copper used in the production of the alloy. On the one hand, furnace refined—as distinct from electro-deposited—copper contains sulphur dioxide, hydrogen sulphide, oxides of carbon, and some oxygen, and is bound to do so from its method of manufacture. Cathode copper, on the other hand, contains hydrogen, which is liberated with the copper at the cathode. It may also contain, and usually does, traces of mechanically imprisoned copper sulphate from the electrolyte, which on melting would give rise to sulphur dioxide. A large proportion of cathode copper, however, is subsequently furnace refined in order to bring it to pitch, and is therefore exposed to the same sources of gaseous contamination, as have been mentioned above. The authors' investigations have shown how difficult it is to remove these gases even *in vacuo*. It is obvious, therefore, that this difficulty would always be present whichever brand of commercial copper were used, and whatever the method of melting adopted. Any practical solution must take account of those facts.

Method 2 has more in its favour. That the furnace temperature should not exceed 1,270 deg. C. would mean less fuel consumption, and the importance of this would be great. Against this, however, should be set the fact that the rate of melting would be diminished, and this would lower the output of the furnace. (The temperature of the furnaces in the foundry of Messrs. J. Dewrance and Co. was at least 1,500 deg. C.) Moreover, it may fairly be argued that this method involves the measurement and regulation of temperature, and that it is preferable to carry this out on the alloy and not on the furnace which is merely melting it. No matter how uniform the temperature of the furnace and the period of melting were maintained, there would always be some uncertainty with regard to the temperature of the metal, particularly on account of the fact that additions of zinc and tin have subsequently to be made in preparing the alloy. For those reasons it appears to the authors that

Method 3 has the most to recommend it from a practical standpoint, i.e., the temperature of the bronze should always be determined before it is poured, in order to be certain that when cast it is within the safety range (1,270 deg. to 1,120 deg. C.). This involves the use of a pyrometer, which can be depended on to give reliable readings of the temperature of the metal. Such pyrometers now exist, and are widely used in the industries. Those who are interested in this question can obtain a great deal of valuable information with regard to the most suitable pyrometer to be used in any given case, by studying the papers contributed to the general discussion on pyrometers and pyrometry at the Faraday Society on November 7, 1917. The extent to which pyrometers are now used may be judged by the fact that "one armament firm alone has six hundred instruments in daily use."*

For measurements up to 1200 deg. C. the pyrometers used are principally thermo-electric; above this, optical and total radiation pyrometers are generally employed. The latter class, therefore, would probably be more suitable in this particular case, because the metal has to be heated well above 1,200 deg. C. The discussion at the Faraday Society elicited the fact that steel-makers now attach great importance to the pouring temperature of steel, which is about 1,600 deg. C. This is a much more difficult problem than that of pouring Admiralty bronze within the safety range. In the former case, quite apart from the difficulty of working at much higher temperatures, attempts are made to keep the casts within 10 deg. to 20 deg. C. of the required figure; in the latter there is a range of about 150 deg. C. within which sound castings can be obtained.

The three methods whose possibilities have been briefly considered are all of a physical nature. A fourth method, whose possibility has not been dealt with in this paper, is essentially chemical in character, and would consist in endeavouring to expel the dissolved gases in the alloy before pouring by the addition of reagents. Several of these are on the market, and it would be interesting if experience with regard to their success or otherwise were forthcoming. The authors are themselves carrying out tests of this kind. The pouring of the alloy within the safety range of temperature, however, would render all such expedients unnecessary, and appears to the authors a more preferable practical solution.

SUMMARY AND CONCLUSION.

1. The best casting temperature for Admiralty bronze is about 1,200 deg. C. Overheating to 1,400 deg. C. and pouring at that temperature is certain to produce porous castings. Pouring below 1,100 deg. C. very often produces unsoundness.

2. The nature of the copper appears to have little or no influence on the final results.

3. Metal melted and cooled in the crucible is sound, even if it has been overheated to 1,400 deg. C. This also applies to previously cast unsound metal.

4. The blowholes are formed by the liberation on cooling of gases dissolved in the metal.

5. The gas collected by heating pieces of castings *in vacuo* is of a complex nature, consisting of the typical furnace gases.

6. Its volume and composition vary with the method of collection, depending on the time the gas remains in the furnace. The two types are:

(*a*) The gas is removed quickly. In this case it has a small volume. There is very little hydrogen and generally a fair proportion of sulphur dioxide and hydrogen sulphide.

(*b*) The gas is heated to constant volume or removed only slowly. In this case the volume is much larger. There is a large percentage of hydrogen—about 50 per cent.—and the sulphur dioxide and hydrogen sulphide are either very low or entirely absent.

7. The zinc is largely responsible for this change, as there is much less difference in the gases collected in the two ways from pure furnace-refined copper. It may act in two ways:

(*a*) It may lower the solubility of these gases in the alloy.

(*b*) By volatilising *in vacuo* it reacts with the sulphur forming zinc sulphide, and this condenses on the inside of the tube.

8. A gas of approximately the same composition is found in both sound and unsound sand-casting and in chill castings. There is not a constant or sufficient difference in the volume of gas obtained from unsound and sound castings to account for the presence of blowholes in the one and their absence from the other.

9. It does not seem likely that the blowholes are formed by the liberation of oxygen, as all the oxygen present in the metal is in the form of oxides of zinc, tin, or copper, if there is much present, the first two of which are very stable compounds and not at all likely to decompose when once formed.

10. The analysis of the gas obtained by heating pure copper very much resembles that of the gas obtained from a copper-tin alloy, and this suggests that the gases which cause unsoundness in the alloy are actually in the copper itself. The volumes of these gases are also about the same.

11. When once the gases are in the metal it is very difficult to extract them.

12. The most suitable practical way of avoiding porous castings would appear to be to determine the temperature of the alloy so as to ensure that it is poured within the range (1,270 deg. to 1,150 deg. C.).

The authors acknowledge with pleasure the assistance of Messrs. R. Sargent and C. C. Smith in the gas analyses, which, owing to the small amount of gas available, have required considerable experimental skill in their execution.

CONTRACT.—The Constructional Engineering Company, Titan Works, Charles Henry-street, Birmingham, state that they have just received a contract from a Government Department for the supply of a complete foundry plant, consisting of twin set of cupolas, charging platform, hoist, fans, &c., to be erected at one of the War Office experimental stations.

* *Nature*, 1917, p. 212.

THE POSSIBILITIES OF THE FERRO-CONCRETE SHIP.*

A Preliminary Survey of the Possibilities of Reinforced Concrete as a Material for Ship Construction.

By Major MAURICE DENNY, S.B.

General.—So long as the efficiency of a mercantile marine is judged by its dividend-earning capacity in free competition, so long will the choice of material for the construction of its units depend on economic considerations. Up to the present for the general trader steel has proved to be the material which gives the greatest return for capital invested, and no material inferior in this respect will permanently displace steel from this position.

In the abnormal circumstances now prevailing, however, when free commercial competition is suspended, it is not necessary to examine the suitability of a material solely from the monetary point of view, and any substance which swells the volume of tonnage by drawing on fresh sources of labour and material has a chance to prove its merit on technical grounds alone. Reinforced concrete at once suggests itself as an alternative to steel, its suitability for general structural purposes being everywhere evident on land, and its application to floating structures being no longer entirely novel. Concrete in itself is strong under compression but has little or no tensile strength; steel is satisfactory in both respects. Concrete is durable and little affected by atmospheric influences; steel is subject to corrosion. Concrete is obtainable in almost any locality; steel is relatively scarce. "Reinforced" concrete combines the two materials in such a way as to exhibit the valuable qualities of each while eliminating in large measure their undesirable properties. For all structures such as beams in which tension and compression co-exist reinforced concrete is particularly suitable, the steel taking tension and the concrete bearing compression. As almost every part of a ship's structure may be considered to be a beam under load, reinforced concrete is therefore not fundamentally unsuited to ship construction. When it is added that the use of reinforced concrete makes practically no demand on the class of labour and material used for steel shipbuilding, the justification for its trial is sufficient, and, in these times, overwhelming.

Experience has proved that steel embedded in concrete is completely protected from corrosion. It has been found that steel which was slightly corroded when bedded, after a lapse of time has shown no trace of rust, which apparently has entered into chemical combination with the surrounding concrete and formed an impervious coat. That this should be the case is fortunate, since the tensional strength of all parts of the structure of a reinforced concrete vessel is solely supplied by the steel. The principal source of deterioration in a steel ship is consequently removed, and the saving of steel shown in comparing a reinforced concrete vessel with a steel ship of the same dimensions must be partly credited to this fact. It is obvious, however, that if the envelope of concrete be ruptured in such a manner as to allow water or other corrosive substance to come in contact with the steel deterioration will at once set in, and will be the more dangerous in that its presence may not be readily detected. As will be shown when considering strength there is every reason to expect cracks in the tensional side of a reinforced concrete member, even when the steel is not stressed beyond a very moderate working load. The volume of opinion seems to be, however, that these cracks are minute and do not permit the ingress of liquid, nor impair the efficiency of the member as a whole. In this connection it should be noted that in a ship's structure the stresses are frequently alternating, often of indeterminate magnitude, and may partake of the nature of shocks. Marine conditions seem thus to be more severe than have usually to be provided for in land work. It has yet to be shown that minute cracks, which are negligible in land structures, may not in marine work develop into fissures sufficiently wide to permit the entry of water, or even, as the result of internal abrasion due to reversal stress, form cavities sufficiently great to destroy the unity of the member as a whole.

Buildings of reinforced concrete are frequently spoken of as being fireproof, but this term is, naturally, a relative one. Considerations of weight in a reinforced concrete ship require that the "cover" shall be reduced to a minimum, and it seems doubtful whether a thickness of concrete of about $\frac{1}{2}$ in. will effectively insulate the reinforcing steel. The damage to the structure, therefore, in way of fire may be as complete as in the case of a steel ship, but it is possible that the destruction may be more localised.

The repairing of local damage in a reinforced concrete ship would seem to be a relatively simple matter. So soon as sufficient concrete and steel in way of the damage has been removed to allow of an adequate scarph between old undamaged and new reinforcement, fresh concrete can be poured into place. Since concrete "sets" under water it is not necessary to retain the vessel in dry dock during the initial stages of hardening. The actual time required for "weathering" will depend on the structural importance and extent of the damaged portion, and unless this is considerable, the vessel can return to service after a much shorter lapse of time than was necessary between launching and delivery.

Watertightness is one of the points which the naval architect will most critically examine when the question arises of replacing steel by reinforced concrete. Fortunately, experience of large tanks in land work is by no means limited, and it is possible to draw certain inferences from the behaviour of these structures. Apart from the water-resisting ability of simple concrete there are various methods of treating the material which fall generally into two categories:—(1) The addition to the concrete during mixing of a waterproofing compound, (2) the treatment of the finished surface with a suitable non-porous material. The first of these is generally believed to reduce the strength, and in the present position of the industry the naval architect will be chary of adopting it. The second comprises: the treatment of the surface with cement mortar well rubbed into the pores, coating with a special mixture, and painting as in a steel ship. Even when none of these special precautions is taken, experience in large tanks shows that though leakage occurs when the concrete is first subjected to water pressure, it gradually diminishes in quantity and finally ceases altogether. This phenomenon may be explained by the deposition of salts in the pores of the material due to the action of the water on the concrete, though the exact chemical reactions seem to be of considerable complexity.

It is interesting to note that, even in this early stage of development, reinforced concrete vessels are being built to carry fuel oil in bulk, experience with land storage tanks and experiments recently made indicating that mineral oil has little or no destructive effect on the material.

Concrete is much more susceptible to abrasion than

Fig. 1.

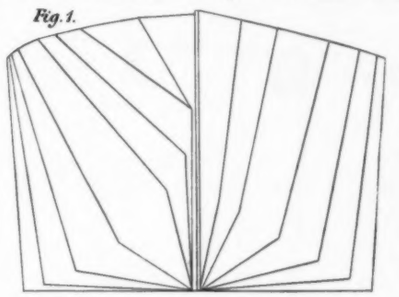
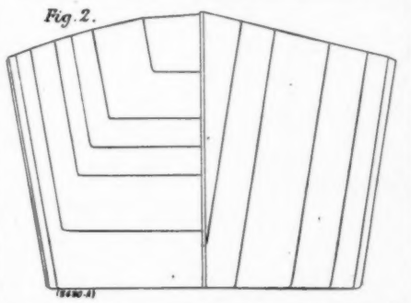


Fig. 2.



steel. The small component particles are rather readily detached from the mass and adequate shielding must therefore be arranged in way of the chafe of cables, cargo, steering chains, &c. If this precaution be neglected the steel reinforcement may be laid bare with the consequent danger of corrosion. The ability of reinforced concrete to stand vibration, whether from propelling or deck machinery, may be called in question. The experience afforded by railway bridges and factory floors shows that little trouble need be feared from this cause, provided that the concrete is not allowed to fail progressively by unsuitable distribution of attachments.

At certain seasons of the year the construction of reinforced concrete vessels may be adversely affected by climatic conditions, a consideration entirely absent from steel shipbuilding, except in so far as the human element is concerned. In frosty weather concreting must not proceed at all, and too rapid drying must be guarded against in the presence of strong sunshine or high winds. After the vessel has been constructed, however, it does not appear that atmospheric influences have any considerable effect; piles in salt water exposed to very severe conditions in the form of alternate wetting and drying at all seasons of the year showing no signs of deterioration.

Constructional.—Concrete when being worked is a plastic material; the processes of construction partake more of the foundry than of the shipyard, and the moulds required in a foundry equally have their place in the reinforced concrete shipyard. Except in one particular method which will be noted later, the whole of the outer and inner surfaces are bounded by a suitable material, the concrete being "cast" into the space between. It is at once evident that the quantity of material required for the moulds is great, and the labour required for their erection will bear a considerable proportion to the total labour required for the ship. It is therefore an obvious economy to arrange that several vessels shall be cast from the same moulds. This has a marked effect on standardisation of type. Where wood is used for the moulds it will probably be found that from five to eight vessels can be built from one lot of shuttering, though considerable repairs and renewals to the woodwork will only be avoided by skilful design and care in erection and dismantling. If the constructor were certain that a large number of exactly similar vessels were to be built he would probably decide to use for the shutters some more durable material than wood.

It seems evident that if the usual ship form be adopted, in which there is curvature in two directions, the amount of work entailed in shaping the shuttering will be at its maximum. The minimum amount of shaping will be given by a rectangular box; but as such a form is usually inadmissible a compromise must be effected. The best result from the point of view both of the naval architect and the reinforced concrete engineer must be sought among the class of "straight frame" forms, which yields at once reasonable figures for resistance in association with curvature in one direction only. Two suggested compromises are shown in Figs. 1 and 2, the "batter" of the sides in Fig. 1 being given in order to reduce the chances of possible damage at the sharp bilge when lying alongside quay walls, and in the case of Fig. 2 to secure "flare" at the bows.

In order that the shuttering may be used several times, it must be so arranged that dismantling does not involve the destruction of the integral parts, and it must be so treated on its inner surfaces that the concrete does not adhere to it. It must be noted that both the interior and exterior walls, or shutters, are not completed before "pouring" commences. It is readily understood that the relatively small space between the walls or shutters, threaded as it is by a network of reinforcement, offers such resistance to the passage of the concrete as to render abortive all attempts to pour through long distances. Only one wall, therefore, is completed, and the other rises in stages as the concreting proceeds. The more fluid the mixture the easier it is to work at this stage; but an excess of moisture brings in its train undesirable qualities in the finished article. On the other hand, it is difficult to ensure that a very dry mixture shall fill all the cavities, and the "setting" is apt to be too rapid. A judicious compromise between these two extremes gives scope for the exercise of care and skill on the part of the workmen engaged on the construction.

Before any concrete is poured, of course, the reinforcement must be placed in position. This is one of the operations which brings into relief the much greater difficulty of marine work as compared with land construction. Even with a straight frame form, beyond the midship length the reinforcement may require to be curved, and as the distance between the interior and exterior walls has been reduced to the minimum to save weight, the accurate placing of the steel and its retention in the correct position is at once of considerable difficulty and great importance. Similar operations in land work are effected under much less stringent conditions. This will probably lead in reinforced concrete shipyards to the development of a class of skilled artisans (with the usual concomitants) as distinct from the "floating" labour frequently employed in land work. To keep the reinforcement in position before, and during, pouring, the component members are wired together so that the reinforcement as a whole assumes the character of a semi-rigid skeleton. The wiring is not taken into account in the strength calculations. As an illustration of the effect on strength of inaccurate placing of the reinforcement it might be observed that if the rods in the section shown in Diagram C, Appendix I, were placed at 1 in. from the lower edge of the member, instead of at $\frac{5}{8}$ in. as intended, the moment of resistance to bending would be decreased by 16 per cent., and the liability of the concrete to crack when subjected to tension would be much increased.

A typical midship section and part profile are shown in Fig. 3, page 384; the main reinforcing elements and their functions are indicated, and the diversity in size is clearly seen. The inspection of a reinforced concrete vessel just prior to the commencement of pouring is apt to produce in the mind of the naval architect an impression other than favourable. The unfamiliar network of rods scarcely suggests serious shipbuilding, and the idea that these should be replaced by the more usual and substantial sectional material at once presents itself. In the case of the frames, for instance, two angle bars connected by light bracing would appear to possess the same strength as the rods in combination with greater ease of erection and immobility during pouring. This system, however, would relegate the concrete to the inferior position of a mere cover for, and support to, a complete steel structure, and would be a return to a method long discarded by reinforced concrete engineers. In modern reinforced concrete work the steel rods fulfil their true function when employed as tension members only, while the concrete takes its full share of the work in compression. It would seem a fundamental error to cling to methods of construction found suitable in one material when dealing with another material of a totally different character. Nevertheless, it is not suggested that a measure of departure from the pure rod or mesh method of reinforcement may not be found advantageous in shipbuilding if thereby construction be simplified, even at the expense of a small additional amount of steel.

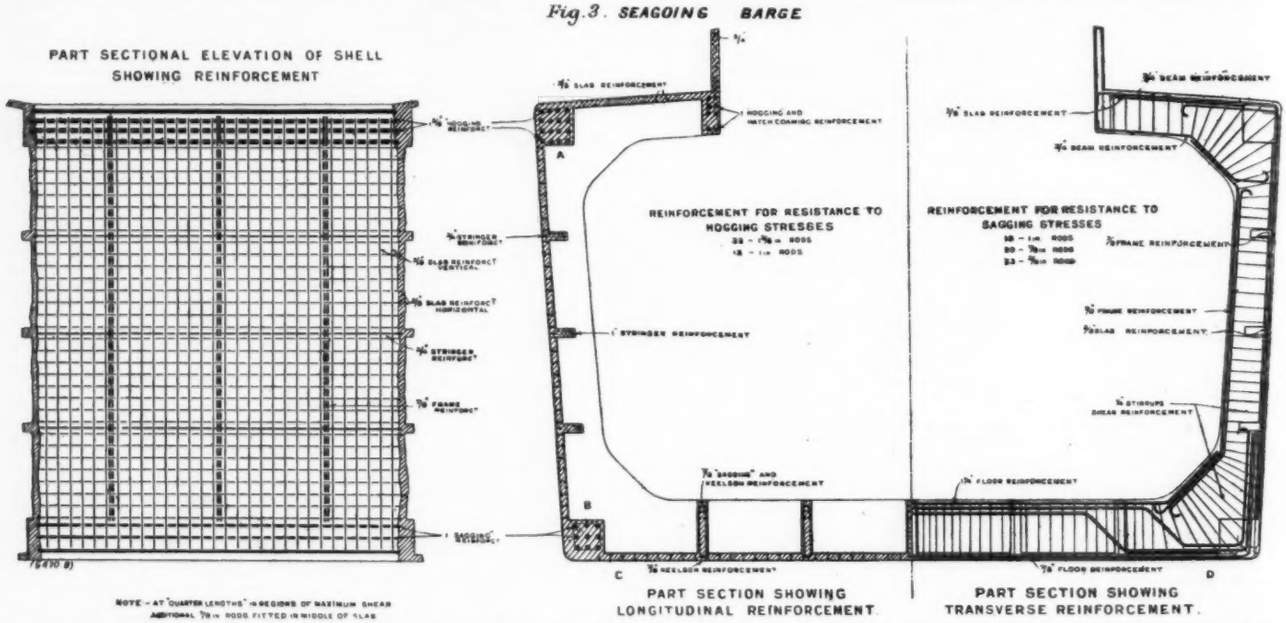
The majority of present-day reinforced concrete designs are based on the production of a vessel which should be cast in one operation, the "monolithic" method, and the foregoing remarks on construction have primarily reference to a monolithic ship. The alternative method is to cast the integral parts separately and assemble them at the slip—the "sectional" method. A few words descriptive of each will be sufficient to outline their characteristics. In the monolithic method, in order that there should be no natural cleavage lines between adjacent areas of concrete in the completed vessel, the pouring would have to proceed continuously and fairly rapidly from the commencement. The large number of hands necessary to make the pouring a

* Paper read at the Spring meetings of the fifty-ninth session of the Institution of Naval Architects, March 22, 1918.

continuous operation, and in addition to effect the concurrent erection of the shuttering, renders impossible the production of a truly monolithic structure in all but very small ships. In practice, large areas are allowed to "set" before the pouring of the adjacent material is commenced, precautions being taken to ensure that the junction of the old and the new material is efficient by the employment of a pure cement "grout" as an adhesive layer. The lines of cleavage are not discernible in the finished product, but precautions are taken to "stagger" the junctions after the manner of butts in shell and deck plating of a steel ship. Notwithstanding the possibility of making joints, it is undesirable to have marked discontinuity of pouring, and the efficiency of the structure when completed is dependent on atmospheric influences and satisfactory labour conditions during construction in a manner unknown in steel ships. When attempting to produce a monolithic structure as an alternative to simple pouring it may be noted that it is possible to apply the concrete by means of a spray, somewhat after the fashion of a sand-blast. A vessel has been built abroad by this process, and experiments are now proceeding in this country. Whether this method will prove more satisfactory than the other will be shown only by the results of practice.

In the "sectional" method portions of the structure more or less extensive are cast from moulds which

Fig. 3. SEAGOING BARGE


PART SECTIONAL ELEVATION OF SHELL SHOWING REINFORCEMENT
REINFORCEMENT FOR RESISTANCE TO HOGGING STRESSES
REINFORCEMENT FOR RESISTANCE TO SAGGING STRESSES
PART SECTION SHOWING LONGITUDINAL REINFORCEMENT.
PART SECTION SHOWING TRANSVERSE REINFORCEMENT.

should be capable of being used a large number of times. A vessel whose sides have irregular curvature, or one in which there is no great extent of parallel middle body, is evidently ill-suited to this form of construction. The sections are assembled in place, and in addition to the grouting" referred to above, steps must be taken to provide for continuity of the local reinforcing material. As it is impossible to allow the general longitudinal reinforcement to be broken abruptly, it is obvious that it cannot form part of the sections, and must therefore be placed in position separately from them. As an example, the shell with its frames between the points A and B, and the bottom with the floors between the points C and D (see Fig. 3), might be cast in sections, which, in the fore and aft direction, may be either one or many frame spaces in length. After the sections are assembled the longitudinal reinforcement at gunwale, bilge, &c., would be placed and the concrete poured round it. The advocates of the sectional system state that watertightness is not difficult of attainment, and that cracks due to the contraction of the concrete on setting are less likely to develop than in the monolithic ship. A complete answer to these two claims will be afforded only by the practical results of ships on service. The sectional system, however, undoubtedly dispenses with a considerable amount of shuttering, and is susceptible to standardisation of parts to a much greater degree than is the monolithic system.

The launching of a vessel subjects the structure to local stresses which may be of considerable magnitude. The steel vessel at the time of launching is as fit to resist these as she ever will be. The process of maturing concrete extends over a period of years and, as might be expected, the increase of strength is very rapid over the early part of that period. By constructing the vessel in such a situation that she may be waterborne without subjecting her to stresses as severe as those imposed by launching, the necessary period of delay between the completion of pouring and floating is reduced. The advantages of floating from a dock, however simple or elaborate it may be, as distinct from launching, are :—

1. The possibilities of failure of the structure during removal from the building berth are much reduced. (2) The number of berths required to execute in a given time any programme is reduced owing to the fact that the number of ships lying "weathering" on dry land is less. (3) The ground can be permanently levelled and prepared so as to form the exterior surface of the bottom shuttering, whereas bottom shuttering is always required (at least in a monolithic vessel) where launching is contemplated. It should be noted that given equal speed of construction the time from laying of keel to delivery to owners will be the same under either method, if, as is essential, the strength on the maiden voyage is to be the same in both cases. In the future, the choice of method will be determined by the financial considerations governing the acquisition and development of the building site.

Strength.—What follows under this heading is rudimentary to the reinforced concrete designer, but is probably not quite so familiar to the naval architect, and in any case will serve to give a quantitative aspect to much of this survey. Concrete suitable for ship construction must be of the highest quality in order to ensure watertightness and to reduce the quantity of the material used. A suitable mixture would have the following composition by volume: Cement, 1; sand, 1½; coarse material, 2½. The permissible working stresses for this mixture would be as follows: direct compressive, 730 lb. per square inch; shearing, 73 lb. per square inch. The tensile strength of any concrete mixture is so low that all text-books and regulations agree in placing it at zero for practical purposes. The modulus of elasticity of concrete appears to vary with the richness of the mixture and so with the ultimate strength; further, concrete does not follow Hooke's law, and therefore the modulus is not even a constant quantity for any one specimen under different stresses. For mixtures usually adopted in practice the upper and lower limits may be taken as 2,000,000 lb. per square inch and 3,000,000 lb. per square inch respectively. For the mixture given above it may be taken at 2,400,000 lb. per square inch.

The fact that reinforced concrete is not a homogeneous substance introduces methods of calculation which are not familiar to the naval architect, who is usually dealing with a material reasonably assumed homogeneous. To produce the same elongations the unit stress in the steel must be to the unit stress in the concrete as the modulus of the steel is to the modulus of the concrete. That is to say, the stress in the steel of a non-ruptured reinforced concrete member must be roughly :—

$$\frac{30{,}000{,}000}{2{,}000{,}000 \text{ to } 3{,}000{,}000}$$

i.e., 15 to 10 times that of the adjacent concrete. From this it follows that the maximum allowable compressive stress in the steel for the mixture quoted is 12.5 times that allowed in the concrete, *i.e.*, 9,000 lb. per square inch, and this figure must not be exceeded if the concrete, which is called upon to resist compression, is not to be stressed beyond the permissible amount. On the other hand, the allowable tensile stress in the steel cannot be fixed by any consideration of the modular ratio, since the strength of the surrounding concrete is taken to be zero. A usual figure for the permissible working tensile stress in the steel is 16,000 lb. per square inch, which figure would correspond to a tensile stress in the concrete of about 1,300 lb. per square inch were such possible. As this cannot be sustained by the concrete there must be rupture of some sort, the possible results of which have been alluded to when considering corrosion.

Lacking rules for the determination of the scantlings of reinforced concrete vessels, a solution may be sought in either of two directions: (*a*) By the application of first principles, or (*b*) by attempting to provide the same strength as is found in corresponding elements of a steel ship. That the latter method will be proved in practice to be the more satisfactory is open to doubt. As is well known, a deliberate provision for corrosion is made in steel vessels, the amount of this being largely independent of size, and allotted to the different elements of the structure in varying degree. If allowance is not made for this a provision to resist corrosion in a steel vessel would appear as a provision to resist stresses in a concrete vessel in which corrosion is absent. Furthermore, for instance, the determination of the moment of inertia of a frame element, in a steel vessel, which is to be repeated in a frame element of a reinforced concrete vessel, requires the inclusion in each case of an indefinite quantity of shell plating; and the results will vary unduly according to the choice made.

The application of first principles does not mean that every element of the structure is treated as a fundamental problem. The naval architect will naturally avail himself of the formulæ to be found in various text-books, which, confirmed by practice, have crystallised in the form of building regulations for land work, such as those of the L.C.C. and the R.I.B.A. The basis of these formulæ is well known; a few examples are given in Appendix I. Consider, for instance, the shell. In a steel vessel experience dictates a minimum as necessary to provide for corrosion and to prevent undue deflection. In reinforced concrete vessels the minimum thickness is also indicated by practical considerations. It is obvious that there must be a certain "cover" round the reinforcement. Good practice seems to place this at about ½ in. Thus the irreducible minimum thickness is about twice ½ in. plus the diameter of the reinforcing element, or, say, 1½ in. But such an arrangement is very uneconomical so far as strength is concerned; the efficient use of material results in a disposition somewhat as indicated in Diagram C, Appendix I. Accordingly the thickness of the concrete must be more than twice that of the cover required if the steel is to be called upon to take any load.

If to take account of possible conditions of load, reinforcement is required in both sides, as is frequently the case, the minimum thickness becomes roughly three times the "cover" plus twice the diameter of the reinforcing element, say, not less than 2 in. As a matter of fact, a very usual thickness employed to-day for a vessel of 1,000 tons deadweight is about 3 in. It is interesting to note that this thickness in association with a 3-ft. frame spacing and stringers 3 ft. apart (a not unusual arrangement) is sufficient to deal with the hydrostatic pressures set up by the maximum draught which need be considered for the ordinary type of cargo carrier. Where the shell is divided into panels by transverse and longitudinal members an interesting feature emerges. The two systems of reinforcement usually run at right angles to the bounding members, and so the relative proportions of the load carried by each system must be assessed before calculations can proceed. It can be shown that when the panel is square the proportion of the load carried in each direction is 50 per cent., and as the panel becomes oblong the proportion of the load carried by the longer system falls away until a stage is reached when it is not economical to reinforce in the longer direction. An example of the use of "reduction factors" is given in Appendix I. In passing, this consideration raises the question as to whether an intercostal in the double bottom of a steel ship is instrumental in reducing the stresses in the plating by producing a smaller panel than would otherwise exist, bearing in mind that the length of the panel so formed is usually three to four times as great as its width.

In a steel ship the effect of the weight of the material

on the stress is usually neglected; in a concrete ship this is taken into account, *vide* example (*c*) in Appendix I.

Turning next to the consideration of the hull as a girder, the bending moments are determined on the usual assumptions. It is possible to determine the moment of inertia of the midship section by a similar method to that employed for steel vessels, multiplying the area of each steel element by the appropriate modular ratio. This, however, is rather a laborious proceeding, and in practice the section is often treated as consisting of a top and bottom flange only, the effect of the vertical walls being omitted. The arm of the resisting moment is then the vertical distance between the centres of figure of the tension and compression members, the concrete being left out of account in the tension member, and the steel and concrete both included in the compression member. To emphasise the effect of modular ratio it may be pointed out that if the percentage area of steel in the compression member is three, the percentage virtual augmentation of area of concrete is three times the modular ratio, or, say, 40 per cent. The bending moment to be resisted, divided by the arm of the resisting moment, gives the total load to be distributed over both flanges of the girder, which, divided by the effective area of each flange, gives the respective mean unit stress therein (see Fig. 3). The hogging bending moment is usually greater than that in the sagging condition, and so it is to be expected that the amount of reinforcing steel at the deck will be greater than that in the bottom, as shown in fact by Fig. 3. In order to avoid superimposing one stress upon another, those parts of the structure, whether of steel or concrete, which are already called upon to resist the principal hydrostatic or other loads are not considered as contributing to the longitudinal strength. For example, the steel rods in the deck slabs are not taken as being effective elements of the structure so far as hogging bending stresses are concerned, notwithstanding the fact that these small members can scarcely be prevented from contributing to the general structural strength. The reduction of resisting moment at the ends, consonant with the decline of bending moment, is effected simply by the gradual elimination of a certain number of the longitudinal rods.

The analysis of the effects of a shearing force show that tensile forces are set up and have to be resisted in the body of the material. This explains why the figure quoted under the paragraph with the side-heading "Strength," as the permissible shearing stress, is so low. In accordance with this fact it is found that the dimensions of a reinforced concrete member are much more dependent on shearing force than is the case in a steel member. The stresses set up by a shearing force can be resisted by rods placed in such a way as to be subjected to pure tension only, thus fulfilling their proper function. It can be shown theoretically that these rods should be placed at about 45 deg. to the top and bottom faces, and the greater the shearing force the more closely should they be arranged. An instance of this method is shown in the floors of the section in Fig. 3. It is not always convenient, however, to introduce such diagonal members, and tension members at right angles to the two faces are frequently substituted therefor. This disposition requires material to resist compressive stresses in a diagonal direction, which duty is legitimately performed by the concrete. Such reinforcement is fitted in frames and floors (see Fig. 3), and takes the form of "stirrups," or rods looped over the tension and compression members. Where not wholly required to resist shear these have the further function of preventing the reinforcement in compression shirking the load and failing through buckling. At the quarter lengths of the ship, where the shearing forces on the structure as a whole reach their maximum, additional vertical reinforcement must be provided in the shell; an alternative method is to bend up some of the main longitudinal members which are no longer required to carry tensile loads.

Weight.—The weight of a cubic foot of plain concrete is about 145 lb. The weight of a cubic foot of reinforced concrete naturally depends on the percentage of steel included therein. For land work the figure for the percentage of area of steel to area of reinforced concrete ranges from 0.5 to 1.5. Taking for the moment a percentage area of steel of 1, the weight of reinforced concrete is about 150 lb. per cubic foot, when steel is 490 lb. per cubic foot. The relative weights are therefore 1 : 3.3.

The mixture quoted in the paragraph headed "Strength," when reinforced with 1 per cent. of steel, has a permissible compressive stress of 810 lb. per square inch. The relative strengths are therefore 16,000 : 810, or 19.8 : 1. This elementary consideration shows that for the same conditions the relative weights are $\frac{19.8}{3.3} : 1$, or 6 : 1. As will be seen shortly, the area of reinforcement in a 1,000-ton vessel is more nearly 4 per cent. than 1 per cent. of the area of reinforced concrete, which reduces the ratio roughly to 4.5 : 1. Again, considering the case where 3 in. of reinforced concrete corresponds to 0.4 in. of steel (an actual case for a large barge), the relative weights are $0.4 \times 490 : 3 \times 150$, or 2.3 : 1.

In the present early stage of development it is natural to expect that widely differing estimates of weight, both as regards concrete and reinforcement, will be advanced by various engineers for the same ship; anyone dealing with reinforced concrete vessels to-day has constant evidence of this. But it is found, as might be expected, that the percentage of reinforcement steadily increases with size of ship. Thus, average figures for percentage weight of steel to total weight of reinforced concrete are, for a 500-ton barge 11 per cent., for a 1,000-ton barge 14 per cent., for a 6,000-ton steamer 22 per cent. This last figure corresponds to a percentage area of steel to reinforced concrete of about 7 per cent., and when it is recalled that an average figure in land work is about 1 per cent., the much more onerous requirements of marine construction are again emphasised. The shipowner is chiefly interested in the loss in deadweight-carrying ability. If a vessel of the same dimensions as the 1,000-ton concrete barge noted above had been built in steel, she would have carried somewhere between 35 per cent. and 40 per cent. more deadweight.

The quantity of steel required in this reinforced concrete vessel is less than one-third that used in the steel ship, but the finished hull weight is nearly twice that of the latter, even when allowances have been made for the omission of cement and paint in the heavier ship. Where internal volume is the measure of the carrying capacity of a vessel, this increase of weight, though not without its drawbacks, is not vital, but where deadweight is the governing factor, the advantages are heavily in favour of the steel structure.

A detailed comparison of the technical particulars of the 6,000-ton deadweight steamer mentioned above will be of interest. It is observed, however, that while the figures quoted for the steel ship are probably accurate, the weight of the reinforced concrete hull is purely estimated, represents a much larger vessel than has yet been attempted in the new material, and lacks the confirmation of practice. With this proviso it may be added that it seems reasonable, though without erring on the heavy side.

	Steel.	Reinforced Concrete.	
	Ft.	Ft.	
Length	375	375	
	Tons.	Tons.	
Displacement ...	9,900	9,900	
Steel	1,920	680	3,150
Concrete	—	2,470	
Wood and outfit ...	400	350	
Machinery	570	570	
Lightweight	2,890	4,070	
Deadweight	7,010	5,830	

From the above it will be noted that 1,180 tons of deadweight is lost, or 17 per cent. of that carried in the steel ship; that the bare hull of the concrete ship is 65 per cent. heavier than that of the steel ship, and that the light weight of the concrete ship is 40 per cent. greater than that of the steel ship. It is impossible to state exactly to what extent the loss in deadweight will restrict the application of reinforced concrete to the construction of cargo carriers, since the cost of construction in reinforced concrete is still somewhat conjectural. Even though quantitative figures are thus unobtainable, it is possible to deduce certain qualitative conclusions which are of value. The following figures represent a reasonable analysis of the manner in which the total cost of the 375-ft. steamer would be made up if built in steel. Bare hull, 53; machinery, 36; remainder, 21; total, 100. If it be allowed that the deadweight carried is a measure of the earning capacity, a reduction of 17 per cent. in this respect must be balanced by a corresponding reduction in prime cost of ship. The reduction in this instance will be 17 per cent. multiplied by 100/53, or 32 per cent. in bare hull cost, since the cost of the other two items remains unaltered. A closer investigation of the question will show that this is only a very rough approximation, and that the absolute cost of running the vessels (even if it be taken to be the same in each case), the percentage of profit assumed, and other matters of accountancy have a powerful influence on the result. These, however, all have the effect of increasing the figure of 32 per cent. noted above, and it can be stated with fair certainty that reinforced concrete will not replace steel for the ordinary cargo carrier unless the hull can be built for considerably less than half the cost of building the same hull in steel (see Appendix II).

In spite of this there appears to be a class of floating structures in which reinforced concrete may well replace steel. Where the additional weight is more than counterbalanced by the durability and reduced prime cost of the new material, there is reason to expect that its adoption will naturally follow. There would therefore seem to be a future for reinforced concrete in such structures as lightships, floating docks, landing stages, hulks, depots ships, and similar craft, and it may confidently be expected that even when the artificial stimulus to reinforced concrete construction provided by present-day conditions is removed the industry will still persist on the sound footing of commercial and technical suitability.

In the preparation of this paepr I wish to acknowledge the assistance of Mr. A. M. Robb, who has been closely associated with the present programme of construction from the beginning, and also the kindness of various concrete engineers who have supplied certain figures and data used in the paper.

APPENDIX I.

Case (*a*).—Beam reinforced for tension only, see diagram A.

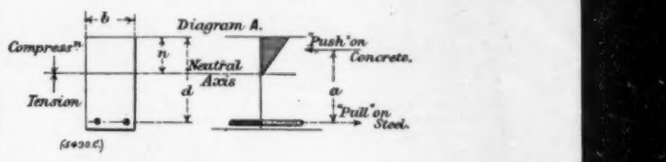
Let A_t = area of reinforcing steel.
a = lever arm, or arm of resisting couple
b = breadth of beam.
d = effective depth of beam.
= distance from centre of reinforcement to compressed edge of beam.
m = modular ratio, steel to concrete.
n = distance of neutral axis from compressed edge of concrete.
r_t = steel ratio.
$= \frac{At}{b \, . \, d}$.

Taking moments about the neutral axis, bearing in mind that the steel takes m times the stress on the concrete—

$$b\,n\,.\,\frac{n}{2} = m\,.\,A_t(d-n)$$

whence—

$$b^2 n^2 + 2\,m\,.\,A_t\,b\,.\,n = 2\,m\,.\,A_t\,.\,b\,.\,d.$$



The solution of this equation is—

$$n = \sqrt{\frac{2\,m\,.\,A_t\,d}{b} + \frac{m^2\,.\,A_t^2}{b^2}} - \frac{m\,.\,A_t}{b}$$

whence—

$$n = \left\{\sqrt{2\,m\,r_t + m^2 r_t^2} - m\,r_t\right\}d. \quad . \quad (1)$$

Also—

$$a = d - \frac{n}{3} \quad . \quad . \quad . \quad . \quad (ii)$$

For a particular case, let a beam be 21 in. by 7 in., reinforced by two 1-in. rods.

Then—
$d = 21 - (\text{"cover"} + \frac{1}{2} \text{ diameter of rod})$.
$= 19.5$ in.
$b = 7$ in.
$b \times d = 136.5$ in.^{2}
$A_t = 1.57$ in.^{2}
$r_t = \frac{1.57}{136.5} = 0.0115$.

Assume—
$$m = 15.$$

Then—
$$n = \{\sqrt{(2 \times 15 \times 0.0115) + (15 \times 0.0115)^2} - (15 \times 0.0115)\}\,19.5 \quad . \quad . \quad \text{from (i)}$$
$= 8.57$ in.

Arm of resisting moment—
$$a = 19.5 - \frac{8.57}{3} = 16.64 \text{ in.} \quad . \quad \text{(see ii)}$$

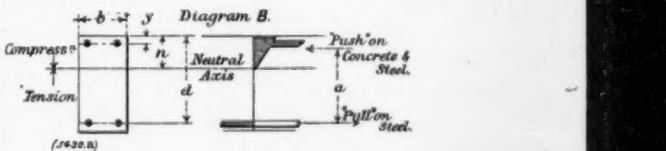
Assume a bending moment of 30,000 ft.-lb.
Then—

$$\text{Tensile stress in steel} = \frac{\text{Bending moment}}{\text{Area of steel} \times \text{lever arm}} = \frac{30{,}000 \times 12}{1.57 \times 16.64} = \underline{13{,}800 \text{ lb./in.}^2}.$$

$$\text{Mean compressive stress in concrete} = \frac{\text{Bending moment}}{\text{Area of concrete} \times \text{lever arm}} = \frac{30{,}000 \times 12}{(7 \times 8.57) \times 16.64} = 360 \text{ lb./in.}^2.$$

Maximum compressive stress in concrete
= twice mean stress.
$= \underline{720 \text{ lb./in.}^2}$.

Case (*b*).—Beam reinforced for compression as well as for tension, see diagram B.



The symbols of Case (*a*) are adopted, with, in addition—
A_c = area of compressive reinforcement.
r_c = compressive steel ratio.
$= \frac{A_c}{b \, . \, d}$.

y = distance of centre of compressive reinforcement from compressed edge.

$$y' = \frac{y}{d}$$

Then, taking moments about the neutral axis:

$$b\,n\,.\,\frac{n}{2} + (m-1)\,A_c\,(n-y) = m \quad A_t\,(d-n)$$

whence—

$$b^2 n^2 + 2\,\{(m-1)\,A_c + m\,.\,A_t\}\,b\,n = 2m\,.\,A_t\,.\,d\,.\,b + 2\,(m-1)\,A_c\,.\,y\,.\,b.$$

The solution of this equation is—

$$n = \sqrt{\frac{2}{b}\{m\,.\,A_t\,d + (m-1)\,A_c\,.\,y\} + \frac{\{(m-1)\,A_c + m\,.\,A_t\}^2}{b^2}} - \frac{(m-1)\,A_c + m\,.\,A_t}{b}$$

$$= [\sqrt{2\,m\,r_t + 2\,(m-1)\,r_c\,.\,y' + \{(m-1)\,r_c + m\,.\,r_t\}^2} - \{(m-1)\,r_c + m\,r_t\}]\,d \quad . \quad . \quad . \quad \text{(iii)}$$

When the reinforcement is the same on both sides of the neutral axis, *i.e.*, when $r_c = r_t$

$$n = \{\sqrt{2\,m\,r_t + 2\,(m-1)\,y' + (2\,m-1)^2\,r_t^2} - (2\,m-1)\,r_t\}\,d \quad . \quad . \quad . \quad . \quad (iv)$$

and when $r_c = 0$

$$n = \{\sqrt{2\,m\,r_t + m^2\,r_t^2} - m\,r_t\}\,d, \text{ cf. Case } (a). \quad (v)$$

Centroid of compressive area from compressed edge—

$$= \frac{\frac{b\,n^2}{3} + (m-1)\,A_c\,.\,y}{b\,n + (m-1)\,A_c} \quad . \quad . \quad . \quad (vi)$$

Consider now the beam in Case (*a*) reinforced on the compressive side by two 1-in. rods—

$$r_c = r_t = 0.0115$$

$$y' = \frac{1.5}{19.5} = 0.077$$

$$n = \{\sqrt{(2\times 15\times .0115) + (2\times 14\times .0115\times .077) + (29\times .0115)^2} - (29\times .0115)\}19.5, \quad . \quad . \text{ from (iv)}$$

$$= 7.02 \text{ in.}$$

Lever arm, $a = 19.5 -$ distance of centroid of compression from compressed edge, see (vi) above—

$$= 19.5 - \frac{\frac{7\times 7.02^2}{3} + (14\times 1.57\times 1.5)}{(7\times 7.02) + (14\times 1.57)}$$

$$= 17.41 \text{ in.}$$

Bending moment, as before = 30,000 ft.-lb.

$$\text{Tensile stress in steel} = \frac{30{,}000\times 12}{1.57\times 17.41}$$

$$= \underline{13{,}150 \text{ lb./in.}^2}.$$

$$\text{Mean compressive stress in concrete} = \frac{30{,}000\times 12}{(49.14+22)\times 17.14}$$

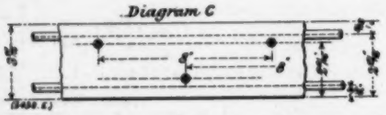
$$= 291 \text{ lb./in.}^2.$$

Maximum compressive stress in concrete = $\underline{582 \text{ lb./in.}^2}$.

Compressive stress in steel = $15\times 582 = \underline{8{,}730 \text{ lb./in.}^2}$.

Case (*c*).—Bottom slab supported on four edges, see diagram C.

Diagram C



Assume dimensions to be 4 ft. 5 in. by 4 ft., then $\frac{b}{l} = 0.906$, $\frac{l}{b} = 1.105$.

Proportion of load assumed to be carried in the direction of the length of the slab—

$$= \frac{1}{1+\left(\frac{l}{b}\right)^4} = 0.40.$$

Proportion of load assumed to be carried in the direction of the breadth of the slab—

$$= \frac{1}{1+\left(\frac{b}{l}\right)^4} = 0.60.$$

Assume depth of water = 17 ft. 8 in.

Hydrostatic pressure = 1,131 lb./ft.^{2}.

Weight of slab = $\underline{45 \text{ lb./ft.}^2}$, see Note (2).

Net upward pressure = 1,086 lb./ft.^{2}.

Slab $3\frac{1}{2}$ in. thick.

Reinforcement in direction of breadth = $\frac{3}{8}$-in. bars, 6-in. centres, top and bottom.

Reinforcement in direction of length = $\frac{3}{8}$-in. bars, 8-in. centres, top and bottom.

Consider 4-ft. span :—

B.M. = $\frac{2}{3}\times\frac{1}{12}\times(0.60\times 1{,}086)\times 4^2 = 580$ ft.-lb. per foot of width.

NOTE.—The factor "$\frac{2}{3}$" in the above expression for the bending moment is introduced because of the fact that the slab is bound along all four edges. The effect of this constraint is, virtually, to reduce the change of shape of the particles of the material, and so, virtually, to reduce the stresses and the bending moment. The introduction of this factor is customary in reinforced concrete work when dealing with moderate-sized slabs.

Reinforcement in the direction of the breadth is outside the other reinforcement, hence—

$$d = 2.94 \text{ in.}$$
$$y = 0.56 \text{ in.}$$
$$y' = 0.19.$$

In 1 ft. of breadth reinforcement in either side is two $\frac{3}{8}$-in. bars = 0.221 in.^{2}.

$$b\times d = 12\times 2.94$$
$$r_c = r_t = 0.00626.$$

In this particular case m was taken to be 12.35.

$$n = \{\sqrt{(2\times 12.35\times 0.00626) + (2\times 11.35\times .00626\times .19) + 23.7\times .00626)^2} - (23.7\times .00626)\}\,2.94 \quad \text{from (iv)}$$

$$= 0.89 \text{ in.}$$

And—

$$a = 2.59 \text{ in.}$$

$$\text{Tensile stress in steel} = \frac{580\times 12}{0.221\times 2.59} = \underline{12{,}100 \text{ lb./in.}^2}.$$

Maximum compressive stress in concrete

$$= \frac{2\times 580\times 12}{\{(12\times 0.89) + (11.35\times 0.221)\}\,2.59}$$

$$= \underline{407 \text{ lb./in.}^2}.$$

Compressive stress in steel = $\underline{5{,}040 \text{ lb./in.}^2}$.

Consider 4-ft. 5-in. span :—

B.M. = $\frac{2}{3}\times\frac{1}{12}\times(0.40\times 1{,}086)\times 4.42 = 472$ ft.-lb. per foot of width.

Inner reinforcement, $\frac{3}{8}$-in. bars, 8-in. centres.

$$d = 2.56 \text{ in.}$$
$$y = 0.94 \text{ in.}$$
$$y' = 0.367.$$
$$b\times d = 12\times 2.56.$$
$$r_c = r_t = 0.0054.$$

In this case

$$n = 0.80.$$
$$a = 2.18.$$

Tensile stress in steel = $\underline{15{,}000 \text{ lb./in.}^2}$.

Maximum compressive stress in concrete = $\underline{450 \text{ lb./in.}^2}$.

Compressive stress in steel = $\underline{5{,}650 \text{ lb./in.}^2}$.

NOTES.—(1) It should be noted that the breadthwise reinforcement is on the outside, *i.e.*, in the more economical position. This is in accordance with the assumption that the breadthwise reinforcement carries the larger share of the load.

(2) It is seen also that the weight of the slab has the effect of reducing the pressure, and so the bending moment, by $\frac{45}{1{,}131}$, or about 4 per cent. Had the slab been at the deck and subject to a load of 225 lb./ft.^{2}, the effect of the weight of the slab would have been to increase the bending moment by 20 per cent.

APPENDIX II.

The following analysis is representative of the manner in which the cost of the 375-ft. steel vessel is made up :—

Bare hull	...	...	...	...	=	100
Machinery	...	...	...	...	=	50
Remainder	...	...	...	...	=	40
Total	...	...	...		=	190

Steel Ship.—

Depreciation at 5 per cent. per annum		=	9.5
Other expenses, per annum	... ...	=	z
Profits at y per cent. of hull cost	...	=	$1.9\,y$

Earnings therefore are $9.5 + z + 1.9\,y$.

Concrete Ship.—

Let x = cost of bare hull, then $x + 90$ = cost of ship.

Depreciation at 5 per cent. per annum	... ...	=	$0.05\,(x + 90)$
Other expenses, per annum	...	=	z
Profits at y per cent. of hull cost	... ...	=	$0.01\,y\,(x + 90)$

Earnings therefore are $z + (0.05 + 0.01\,y)\,(x + 90)$

Now, allowing that the concrete ship carries 83 per cent. of the deadweight carried by the steel ship, and that the deadweight is a measure of the earning capacity, then—

0.83 (steel ship earnings) = concrete ship earnings,

whence—

$0.83\,(9.5 + z + 1.9\,y) = z + (0.05 + 0.01\,y)\,(x + 90)$.

Solving—

$$x = 67.7 - \frac{17\,z}{5 + y}$$

or, say,

$$x = 68 - \frac{17\,z}{5 + y}$$

Then, on the assumptions taken, and for varying values of y (percentage of profits) the table below is derived—

y					x
0	...	...	...	...	$68 - 3.4\,z$
5	...	...	...	...	$68 - 1.7\,z$
10	...	...	...	...	$68 - 1.1\,z$
15	...	...	...	...	$68 - 0.85\,z$
20	...	...	...	...	$68 - 0.68\,z$

From the above it is evident that to obtain equality of profit percentage under the assumptions taken the cost of the bare concrete hull must under no circumstances exceed 68 per cent. that of the bare steel hull.

For the "other expenses," including management, stores, wages, insurance, docking, repairs, coal, dues loading and discharging expenses, &c., the figure of 50 is not unreasonable, representing 26 per cent. of total cost of ship per annum.

Substituting this value for z in the table above—

y						x
0	...	...	...	...	...	− 102
5	...	...	...	...	...	− 17
10	...	...	...	...	...	13
15	...	...	...	...	...	26
20	...	...	...	...	...	34

Thus when freights are low the concrete ship cannot pay expenses, and when the steel ship is earning 20 per cent. profits the cost of the bare concrete hull must not exceed 34 per cent. of the cost of the bare steel hull if the same percentage of profit is to be earned by the concrete ship.

The figures above are qualitative only, and are not advanced as a complete and detailed analysis of the problem.

CATALOGUES.

Lock Nut.—Messrs. Lewis and Sawyer, 8, Bush lane, Cannon street, E.C. 4, send particulars of the Ross lock nut. Two nuts are connected by spigot and socket faces, both spigot and socket being cut eccentric to the axis of the threaded hole. The threaded holes are in axial line and continuous thread in normal position, and the nut is easily run on and tightened. After tightening, a part turn is given to the upper half, locking the two halves against the thread. The hexagon sides to be brought into line to slack the nut are marked.

Renewed Electric Lamps.—The Renew Electric Lamp Company, Limited, Harrow road, Willesden Junction, London, N.W. 10, are making a special business of renewing old and worn out lamps by a special patented process. The old lamp glasses are cleaned inside and out and a new British made drawn wire filament attached. Half watt lamps are dealt with. The cost appears to be about one half the present price of new lamps for small sizes, to about two thirds for the large. The catalogue gives a price list.

Building Structures.—Complete buildings from factories to small schools or chapels are made in parts and sent off ready for quick erection by Messrs. David Rowell and Co., Limited, 14, Howick place, London, S.W. 1, who also supply any parts such as principals, complete roofs, bare frames, staircases, ventilating systems, &c. The material is all wood, all steel, or both. The catalogue received gives full measurements and illustrations, and quotes prices for the structures erected. Concrete foundations may also be ordered. Many varieties of roofing, glazing, walls, &c., are provided.

Motor Lorries.—The Austin Motor Company, Limited, Northfield, Birmingham, send a copy of a handbook of instructions for the lubrication and adjustment of their 2 ton to 3 ton lorry. There are 46 pages of illustrations and letterpress dealing with starting, lubrication, carburettor, dynamo lighting, magneto, and various parts of the engine, steering gear, axles, wheels, &c. The information is well classified and clearly stated. The book should be of great value to drivers and to engineers responsible for the upkeep of these vehicles It is well printed in clear type and strongly bound in limp cloth with a button flap.

Digging Buckets.—Buckets for use with hoisting and conveying gear have become quite a separate machine, and are variously termed "self acting," "automatic," "dumping," &c. A 64 page catalogue entirely devoted to such buckets comes from the Brown Hoisting Machinery Company, of Cleveland, Ohio, U.S.A. The grab bucket spreads out two spades on a heap of coal, gravel, &c., or ordinary soil, and digs up a load which, after being conveyed to its place, is discharged rapidly or gradually, in whole or in part as required. These are made in a variety of types and in capacities from 150 cub. ft. to 1,500 cub. ft. Powerful digging buckets with renewable manganese steel teeth are made for 190 cub. ft. and 330 cub. ft. capacity. Drag-line buckets for clay and sticky material and automatic dumping tubs in several forms for different purposes or situations are also shown. All are fully described, with tables of measurements, and are illustrated in detail.

Stoking Machines.—A catalogue describing and illustrating a coker stoking machine, with very full and instructive particulars, comes from Messrs. Ed. Bennis and Co., Limited, Little Hulton, Bolton. The object in this design is to provide a continuous mechanical feed of coal to a mechanically operated grate, so as to maintain a steady combustion, practically without smoke. The black coal is turned into coke as it is pushed along the grate surface, until a clear red fire prevails at the back. The smoke is developed at the front and consumed as it passes over the clear fire. The grate is self cleaning, clinkers being discharged at the far end. The air supplies are different for the front and back portions, so that different pressures can be used and steam jets are used in the front or "lighting" portion. There has always been a difficulty in burning certain classes of coal with full economy, without emitting a considerable amount of smoke. Smoke can be consumed in these cases, but only by reducing the steam raising power of the boiler. Any of our readers can obtain a copy of this catalogue by writing to Messrs. Bennis, and study the mechanism for themselves. A boiler test quoted in full in the catalogue shows 47.36 lb. of coal burned per square foot of grate surface per hour, with 9.4 lb. of water evaporated per pound of coal. The coal was a medium slack containing 10.6 per cent. ash and 5.8 per cent. of moisture.

LOCKWOOD'S PRICE BOOK FOR 1918.—The full title of this publication is "Lockwood's Builder's, Architect's Contractor's and Engineer's Price Book." It is edited by Mr. R. Stephen Ayling, and is issued at the price of 4*s.* net by Messrs. Crosby Lockwood and Son, 7, Stationers' Hall Court, Ludgate Hill, E.C. 4. It gives a vast amount of prices of material and labour for every description of work connected with the above trades and professions, also information on the manufacturers of special articles and machinery, and indications as to prices. Since practically the whole of the building material is under Government control and is being used in the erection of munition works, factories, hutments, &c., as the publishers state in the preface, the revision of the price book of this class has been a most difficult task. The publishers are to be congratulated upon having brought out the present edition notwithstanding their handicaps. The book retains its usual features, and is most carefully indexed.